Service Guide

HP EPM E4418A/E4419A

(EPM-441A/442A)

Power Meters

HP Part no. E4418-90006

© Copyright Hewlett-Packard Company

All rights reserved. Reproduction, adaptation, or translation without prior written permission is prohibited, except as allowed under the copyright laws.

Printed in the UK.

Legal Information

Notice

Information contained in this document is subject to change without notice. Hewlett-Packard makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. Hewlett-Packard shall not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishings, performance, or use of this material. No part of this document may be photocopied, reproduced, or translated to another language without the prior written consent of HP.

Certification

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology, to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

Warranty

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Hewlett-Packard Company will at its option, either repair or replace products which prove to be defective. For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges, duties, and taxes for products returned to HP from another country. HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or firmware will be uninterrupted or error free.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance. NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Exclusive Remedies

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

Equipment Operation

Warnings and Cautions

This guide uses warnings and cautions to denote hazards.

WARNING **A warning calls attention to a procedure, practice or the like, which, if not correctly performed or adhered to, could result in injury or the loss of life. Do not proceed beyond a warning until the indicated conditions are fully understood and met.**

Caution A caution calls attention to a procedure, practice or the like which, if not correctly performed or adhered to, could result in damage to or the destruction of part or all of the equipment. Do not proceed beyond a caution until the indicated conditions are fully understood and met.

Personal Safety Considerations

WARNING **This is a Safety Class I product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor, inside or outside the instrument, is likely to make the instrument dangerous. Intentional interruption is prohibited.**
If this instrument is not used as specified, the protection provided by the equipment could be impaired. This instrument must be used in a normal condition (in which all means of protection are intact) only.
No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock, do not remove covers.
For continued protection against fire hazard, replace the line fuse(s) only with fuses of the same type and rating (for example, normal blow, time delay, etc.). The use of other fuses or material is prohibited.

General Safety Considerations

WARNING **Before this instrument is switched on, make sure it has been properly grounded through the protective conductor of the ac power cable to a socket outlet provided with protective earth contact.**
Any interruption of the protective (grounding) conductor, inside or outside the instrument, or disconnection of the protective earth terminal can result in personal injury.

Caution Any adjustments or service procedures that require operation of the instrument with protective covers removed should be performed only by trained service personnel.

Markings

The CE mark shows that the product complies with all the relevant European legal Directives (if accompanied by a year, it signifies when the design was proven.

This is the symbol of an Industrial Scientific and Medical Group 1 Class A product.

The CSA mark is a registered trademark of the Canadian Standards Association.

External Protective Earth Terminal.

While this is a Class I product, provided with a protective earthing conductor in a power cord, an external protective earthing terminal has also been provided. This terminal is for use where the earthing cannot be assured. At least an 18AWG earthing conductor should be used in such an instance, to ground the instrument to an assured earth terminal.

IEC 1010-1 Compliance

This instrument has been designed and tested in accordance with IEC Publication 1010-1 +A1:1992 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use and has been supplied in a safe condition. The instruction documentation contains information and warnings which must be followed by the user to ensure safe operation and to maintain the instrument in a safe condition.

List of Related Publications

The HP EPM-441A and HP EPM-442A *User's Guides* are also available in the following languages:

- English Language User's Guide - Standard
- German Language User's Guide - Option ABD
- Spanish Language User's Guide - Option ABE
- French Language User's Guide - Option ABF
- Italian Language User's Guide - Option ABZ
- Japanese Language User's Guide - Option ABJ

HP EPM-441A/442A Service Guide is available by ordering Option 915.

HP EPM-441A/442A CLIPs (Component Location and Information Pack) is available by ordering E4418-90007.

Sales and Service Offices

If you need technical assistance with a Hewlett-Packard test and measurement product or application please contact the Hewlett-Packard office or distributor in your country.

Asia Pacific:

Hong Kong: (852) 2599 7889

India: (91-11) 647 2311

Japan:

Hewlett-Packard Japan Ltd.
Measurement Assistance Center
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo 192, Japan
Tel: (81-426) 56-7832
Fax: (81-426) 56-7840

Korea: (82-2) 769 0800

Malaysia: (60-3) 291 0213

Philippines: (63-2) 894 1451

PRC: (86-10) 6505 0149

Singapore: (1800) 292 8100

Taiwan: (886-3) 492 9666

Thailand: (66-2) 661 3900

For countries in Asia Pacific not listed contact:

Hewlett-Packard Asia Pacific Ltd.
17-21/F Shell Tower, Times Square,
1 Matheson Street, Causeway Bay,
Hong Kong
tel: (852) 2599 7070
fax: (852) 2506 9285

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130
Australia
1 800 629 485

Canada:

Hewlett-Packard Canada Ltd.
5150 Spectrum Way
Mississauga, Ontario
L4W 5G1
(905) 206 4725

In Europe, Africa and Middle East please call your local HP sales office or representative:

Austria: (1) 25000-0

Belgium and Luxembourg: (02) 778 3417

Baltic Countries: (358) 08872 2100

Czech Republic: (0042) 2-4743111

Denmark: 45 99 10 00

Finland: (90) 88 721

France: (0) 1 69.29.41.14

Germany: (0180) 532 62-33

Greece: (1) 7264045

Hungary: (1) 252 4705

Ireland: (01) 284 4633

Israel: (03) 5380 333

Italy: 02 - 92 122 241

Netherlands: (020) 547 6669

Norway: (22) 73 56 50

Poland: (22) 608 7700

Portugal: (11) 482 85 00

Russia: tel (7/095) 928 6885, fax (7/095) 916 9844

South Africa: (011) 806 1000

Spain: (34) 1 631 1323

Sweden: (08) 444 22 77

Switzerland: (01) 735 7111

Turkey: (212) 224 59 25

United Kingdom: (01344) 366 666

For countries in **Europe/Middle East** and **Africa** not listed, contact:

Hewlett-Packard
International Sales Europe
Geneva, Switzerland
Tel: +41-22-780-4111
Fax: +41-22-780-4770

Latin America:

Hewlett-Packard
Latin American Region Headquarters
5200 Blue Lagoon Drive
9th Floor
Miami, Florida 33126
USA
(305) 267 4245/4220

United States:

Hewlett-Packard Company
Test and Measurement Organization
5301 Stevens Creek Blvd.
Bldg. 51L-SC
Santa Clara, CA 95052-8059
1 800 452 4844

In any correspondence or telephone conversations, refer to the power meter by its model number (which is on the front panel) and full serial number (which is on the rear panel). With this information, the HP representative can quickly determine whether your unit is still within its warranty period.

Returning Your Power Meter for Service

Use the information in this section if you need to return your power meter to Hewlett-Packard.

Package the Power Meter for Shipment

Use the following steps to package the power meter for shipment to Hewlett-Packard for service:

1. Fill in a blue service tag (available at the end of this guide) and attach it to the power meter. Please be as specific as possible about the nature of the problem. Send a copy of any or all of the following information:
   - Any error messages that appeared on the power meter display.
   - Any information on the performance of the power meter.

Caution Power meter damage can result from using packaging materials other than those specified. Never use styrene pellets in any shape as packaging materials. They do not adequately cushion the power meter or prevent it from shifting in the carton. Styrene pellets cause power meter damage by generating static electricity and by lodging in the rear panel.

2. Use the original packaging materials or a strong shipping container that is made of double-walled, corrugated cardboard with 159 kg (350 lb) bursting strength. The carton must be both large enough and strong enough to accommodate the power meter and allow at least 3 to 4 inches on all sides of the power meter for packing material.
3. Surround the power meter with at least 3 to 4 inches of packing material, or enough to prevent the power meter from moving in the carton. If packing foam is not available, the best alternative is SD-240 Air Cap ™ from Sealed Air Corporation (Commerce, CA 90001). Air Cap looks like a plastic sheet covered with 1-1/4 inch air filled bubbles. Use the pink Air Cap to reduce static electricity. Wrap the power meter several times in the material to both protect the power meter and prevent it from moving in the carton.
4. Seal the shipping container securely with strong nylon adhesive tape.
5. Mark the shipping container “FRAGILE, HANDLE WITH CARE” to ensure careful handling.
6. Retain copies of all shipping papers.

About this Guide

Chapter 1: Specifications

This chapter lists the power meter's specifications and describes how to interpret these specifications.

Chapter 2: Performance Tests

This chapter contains procedures which allow you to test the power meter's electrical performance to it's specifications.

Chapter 3: Adjustments

This chapter contains checks and adjustments that ensure proper performance of the power meter.

Chapter 4: Theory of Operation

This chapter describes how each of the power meter's individual assemblies operate.

Chapter 5: Replaceable Parts

This chapter details the power meter's replaceable parts. It also explains how to assemble and disassemble the power meter.

Table of Contents

Page

Legal Information iii
Equipment Operation v
Personal Safety Considerations v
General Safety Considerations vi
Markings vi
IEC 1010-1 Compliance vii
List of Related Publications viii
Sales and Service Offices ix
Returning Your Power Meter for Service xii
About this Guide xiii

Specifications 1-1
Introduction 1-2
Power Meter Specifications 1-3
Meter 1-3
Accuracy 1-4
Power Reference 1-5
Power Meter Supplemental Characteristics 1-6
Power Reference 1-6
Measurement Speed 1-6
Zero Drift of Sensors 1-7
Measurement Noise 1-7
Settling Time 1-9
Power Sensor Specifications 1-12
General Characteristics 1-13
Rear Panel Connectors 1-13
Environmental Characteristics 1-14
General Conditions 1-14
Operating Environment 1-14
Storage Conditions 1-14
General 1-15
Dimensions 1-15
Weight 1-15
Safety 1-15
Remote Programming 1-15
Non-Volatile Memory 1-16

Performance Tests 2-1
Introduction 2-2
Equipment Required 2-3
Performance Test Record 2-4
Performance Tests 2-4
Calibration Cycle 2-4
Test Procedures 2-4
Zero Test 2-5
Specification 2-5
Description 2-5
Equipment 2-5
Test Setup 2-5
Procedure 2-6
Instrument Accuracy Test 2-7
Specification 2-7
Description 2-7
Equipment 2-7
Test Setup 2-7
Procedure 2-8
Power Reference Level Test 2-10
Description 2-10
Equipment 2-11
Test Setup 2-11
Procedure 2-11
HP E-Series Power Sensor Interface Test 2-14
Procedure 2-14
HP E-Series Power Sensor Functional Test 2-15
Description 2-15
Equipment 2-15
Procedure 2-16
Performance Test Record 2-18

Adjustments 3-1
Introduction 3-2
Safety Considerations 3-2
Equipment Required 3-3
Post-Repair Adjustments 3-3
Power Reference Oscillator Frequency Adjustment 3-4
Description 3-4
Equipment 3-4
Procedure 3-4
Power Reference Oscillator Level Adjustment 3-6
Description 3-6

Equipment 3-8
Procedure 3-8
Measurement Uncertainty 3-11
Display Brightness and Contrast Adjustment 3-12
Introduction 3-12
Procedure 3-12

Theory of Operation 4-1
Introduction 4-2
A1 Power Supply 4-3
A2 Processor Assembly 4-4
A3 Front Panel Assembly 4-7
A4 Interface Assembly 4-8
A5 Daughter Assembly 4-9
A6 Measurement Assembly 4-10

Replaceable Parts 5-1
Introduction 5-2
Assembly Part Numbers 5-3
Front Panel Connector Repair 5-5
Firmware Upgrades 5-6
Downloading Firmware 5-6
Assembly and Disassembly Guidelines 5-7
Removing the Power Meter Cover 5-7
Removing the A1 Power Supply Assembly 5-8
Removing the A2 Processor Assembly 5-9
Removing the A4 Interface Assembly 5-10
Removing the A5 Daughter or A6 Measurement Assemblies 5-11
Removing the A7 Fan Assembly 5-12
Removing the Power Meter Battery (BT1) 5-13
Removing the A3 Front Panel Assembly 5-14
Replacing the Front Panel Power Reference Cable Assembly 5-17
Replacing the Rear Panel Power Sensor Cable Assemblies (Options 002 and 003) 5-18
Replacing the Rear Panel Power Reference Cable Assembly (Option 003) 5-20

List of Figures

Page

2-1 Zero Test Setup 2-5
2-2 Instrument Accuracy Test Setup 2-7
2-3 Power Reference Level Test Setup 2-11
2-4 Sensor Functional Test Setup 2-16
2-5 Sensor Functional Test Setup with Attenuator 2-17
3-1 Adjustment Setup 3-4
3-2 A2L9 Adjustment Location 3-5
3-3 Adjustment Setup 3-6
3-4 A2R90 Adjustment Location 3-10

List of Tables

Page

1-1 Zero Set Specifications 1-4
1-2 Noise Multiplier 1-7
1-3 Power Sensor Specifications± 1-8
1-4 Settling Time 1-9
1-5 Settling Time 1-10
2-1 Required Equipment 2-3
2-2 Zero Test Results 2-6
2-3 Instrument Accuracy Results 2-9
2-4 Power Reference Level Result 2-13
2-5 Functional Test Result 2-17
2-6 Performance Test Record 2-18
3-1 Post Repair Adjustments, Tests, and Checks 3-3

1

Specifications

Introduction

This chapter details the power meter's specifications and supplemental characteristics.

Specifications describe the warranted performance and apply after a 30 minute warm-up. These specifications are valid over the power meter's operating and environmental range unless otherwise stated and after performing a zero and calibration.

Supplemental characteristics, which are shown in italics, are intended to provide information useful in applying the power meter by giving typical, but nonwarranted performance parameters. These characteristics are shown in italics or denoted as "typical", "nominal" or "approximate".

For information on measurement uncertainty calculations, refer to HP Application Note 64-1A, "Fundamentals of RF and Microwave Power Measurements", Literature Number 5965-6630.

Power Meter Specifications

Meter

Frequency Range

100 kHz to 50 GHz and 75 GHz to 110 GHz, power sensor dependent

Power Range

-70 dBm to +44 dBm (100 pW to 25 W), power sensor dependent

Power Sensors

Compatible with all HP 8480 series power sensors and HP ECP-series power sensors.

Single Sensor Dynamic Range

90 dB maximum (HP ECP-series power sensors)
50 dB maximum (HP 8480 series power sensors)

Display Units

Absolute: Watts or dBm
Relative: Percent or dB

Display Resolution

Selectable resolution of:

1.0, 0.1, 0.01 and 0.001 dB in logarithmic mode, or
1, 2, 3 and 4 significant digits in linear mode

Default Resolution

0.01 dB in logarithmic mode
3 digits in linear mode

Accuracy

Instrumentation

Absolute: ±0.02 dB (Logarithmic) or ±0.5% (Linear). (Refer to the power sensor linearity specification in your power sensor manual to assess overall system accuracy.)
Relative: ±0.04 dB (Logarithmic) or ±1.0% (Linear). (Refer to the power sensor linearity specification in your power sensor manual to assess overall system accuracy.)

Zero Set (digital settability of zero): Power sensor dependent (refer to Table 1-1). For HP ECP-series power sensors, this specification applies when zeroing is performed with the sensor input disconnected from the POWER REF.

Table 1-1: Zero Set Specifications

Power Sensor	Zero Set
HP 8481A	±50 nW
HP 8481B	±50 µW
HP 8481D	±20 pW
HP 8481H	±5 µW
HP 8482A	±50 nW
HP 8482B	±50 µW
HP 8482H	±5 µW
HP 8483A	±50 nW
HP 8485A	±50 nW
HP 8485D	±20 pW
HP R8486A	±50 nW
HP R8486D	±30 pW
HP Q8486A	±50 nW
HP Q8486D	±30 pW
HP W8486A	±200 nW
HP 8487A	±50 nW
HP 8487D	±20 pW
HP ECP-E18A	±50 pW
HP ECP-E26A	±50 pW

Power Reference

Power Output

1.00 mW (0.0 dBm). Factory set to ±0.7% traceable to the US National Institute of Standards and Technology.

Accuracy

±1.2% worst case (±0.9% rss) for one year.

Power Meter Supplemental Characteristics

Power Reference

Frequency

50 MHz nominal

SWR

1.05 maximum

Connector

Type N (f), 50 Ω

Measurement Speed

Over the HP-IB, three measurement speed modes are available as shown, along with the typical maximum measurement speed for each mode:

- ***Normal:** 20 readings / second*
- ***x2:** 40 readings / second*
- ***Fast:** 200 readings / second, for HP ECP-series power sensors only*

Maximum measurement speed is obtained using binary output in free run trigger mode.

Zero Drift of Sensors

Power sensor dependent (refer to Table 1-3).

Measurement Noise

Power sensor dependent (refer to Table 1-2 and Table 1-3).

Averaging effects on measurement noise. Averaging over 1 to 1024 readings is available for reducing noise. Table 1-3 provides the measurement noise for a particular power sensor with the number of averages set to 16 for normal mode and 32 for x2 mode. Use the "Noise Multiplier" for the appropriate mode (normal or x2) and number of averages to determine the total measurement noise value.

For example, for an HP 8481D power sensor in normal mode with the number of averages set to 4, the measurement noise is equal to:

(<45 pW x 2.75) = <124 pW

Table 1-2: Noise Multiplier

Number of Averages	1	2	4	8	16	32	64	128	256	512	1024
Noise Multiplier (Normal Mode)	*5.5*	*3.89*	*2.75*	*1.94*	*1.0*	*0.85*	*0.61*	*0.49*	*0.34*	*0.24*	*0.17*
Noise Multiplier (x2 mode)	*6.5*	*4.6*	*3.25*	*2.3*	*1.18*	*1.0*	*0.72*	*0.57*	*0.41*	*0.29*	*0.2*

Table 1-3: Power Sensor Specifications±

Power Sensor	*Zero Drift*[1]	*Measurement Noise*[2]
HP 8481A	*<±10 nW*	*<110 nW*
HP 8481B	*<±10 µW*	*<110 µW*
HP 8481D	*<±4 pW*	*<45 pW*
HP 8481H	*<±1 µW*	*<10 µW*
HP 8482A	*<±10 nW*	*<110 nW*
HP 8482B	*<±10 µW*	*<110 µW*
HP 8482H	*<±1 µW*	*<10 µW*
HP 8483A	*<±10 nW*	*<110 nW*
HP 8485A	*<±10 nW*	*<110 nW*
HP 8485D	*<±4 pW*	*<45 pW*
HP R8486A	*<±10 nW*	*<110 nW*
HP R8486D	*<±6 pW*	*<65 pW*
HP Q8486A	*<±10 nW*	*<110 nW*
HP Q8486D	*<±6 pW*	*<65 pW*
HP W8486A	*<±40 nW*	*<450 nW*
HP 8487A	*<±10 nW*	*<110 nW*
HP 8487D	*<±4 pW*	*<45 pW*
HP ECP-E18A	*<± 15 pW*	*<70 pW*
HP ECP-E26A	*<± 15 pW*	*<70 pW*

1. Within 1 hour after zero set, at a constant temperature, after a 24 hour warm-up of the power meter.
2. The number of averages at 16 (for normal mode) and 32 (for x2 mode), at a constant temperature, measured over a 1 minute interval and 2 standard deviations. For HP ECP-series power sensors the measurement noise is measured within the low range. Refer to the relevant power sensor manual for further information.

Settling Time

0 to 99% settled readings over the HP-IB.

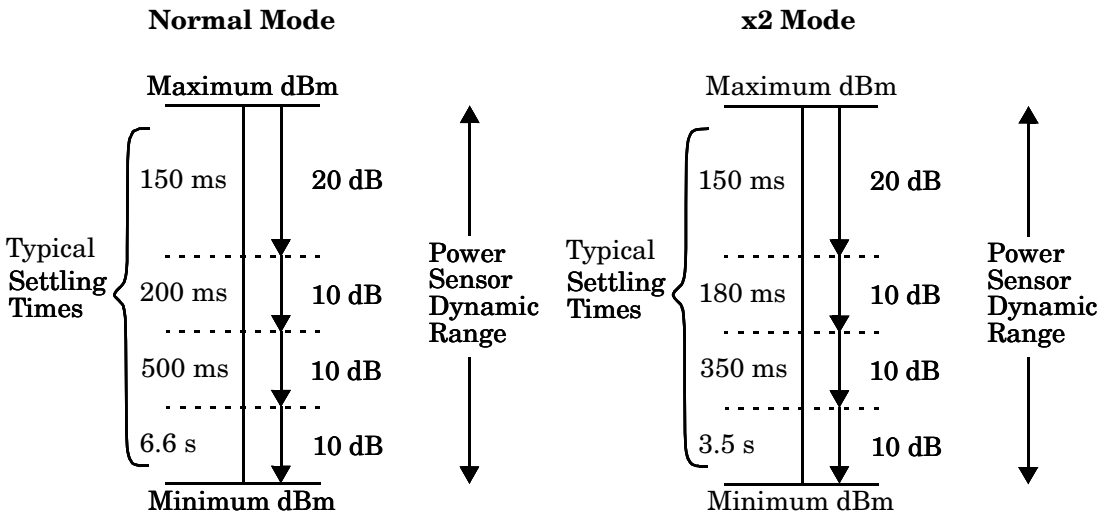
For HP 8480 series power sensors

Manual filter, 10 dB decreasing power step:

Table 1-4: Settling Time

Number of Averages	1	2	4	8	16	32	64	128	256	512	1024
Settling Time (s) (Normal Mode)	*0.15*	*0.2*	*0.3*	*0.5*	*1.1*	*1.9*	*3.4*	*6.6*	*13*	*27*	*57*
Response Time (s) (x2 mode)	*0.15*	*0.18*	*0.22*	*0.35*	*0.55*	*1.1*	*1.9*	*3.5*	*6.9*	*14.5*	*33*

Auto filter, default resolution, 10 dB decreasing power step, normal and x2 *speed modes:*



For HP ECP-series power sensors

In FAST mode, within the range -50 dBm to +17 dBm, for a 10 dB decreasing power step, the settling time is 10 ms[1] for the HP EPM-441A and 20 ms[1] for the HP EPM-442A

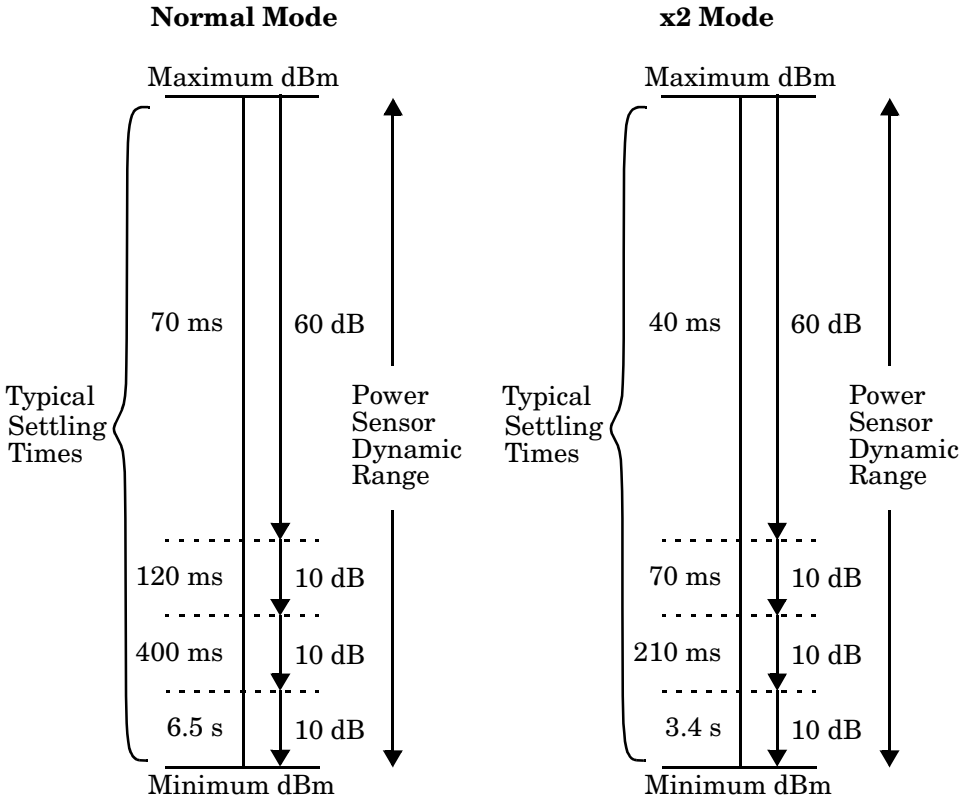
[1]When a decreasing power step crosses the power sensor's auto-range switch point, add 25 ms. Refer to the relevant power sensor manual for further information.

For HP ECP-series power sensors in normal and x2 *speed modes, manual filter, 10 dB decreasing power step:*

Table 1-5: Settling Time

Number of Averages	1	2	4	8	16	32	64	128	256	512	1024
Settling Time (s) (Normal Mode)	*0.07*	*0.12*	*0.21*	*0.4*	*1*	*1.8*	*3.3*	*6.5*	*13*	*27*	*57*
Response Time (s) (x2 mode)	*0.04*	*0.07*	*0.12*	*0.21*	*0.4*	*1*	*1.8*	*3.4*	*6.8*	*14.2*	*32*

Auto filter, default resolution, 10 dB decreasing power step, normal and x2 speed modes:



Power Sensor Specifications

Definitions

Zero Set

In any power measurement, the power meter must initially be set to zero with no power applied to the power sensor. Zero setting is accomplished within the power meter by digitally correcting for residual offsets.

Zero Drift

This parameter is also called long term stability and is the change in the power meter indication over a long time (usually one hour) for a constant input power at a constant temperature, after a defined warm-up interval.

Measurement Noise

This parameter is also known as short term stability and is specified as the change in the power meter indication over a short time interval (usually one minute) for a constant input power at a constant temperature.

General Characteristics

Rear Panel Connectors

Recorder Output

Analog 0-1 Volt, 1 kΩ output impedance, BNC connector

HP-IB

Allows communication with an external controller.

Ground

Binding post, accepts 4 mm plug or bare-wire connection

Line Power

- ***Input Voltage Range:*** *85 to 264 Vac, automatic selection*
- ***Input Frequency Range:*** *47 to 63 Hz*
- ***Power Requirement:*** *approximately 50 VA (14 Watts)*

Environmental Characteristics

General Conditions

Complies with the requirements of the EMC Directive 89/336/EEC. This includes Generic Immunity Standard EN 50082-1: 1992 and Radiated Interference Standard EN 55011:1991/CISPR11:1990, Group 1 - Class A.

Operating Environment

Temperature

0ºC to 55ºC

Maximum Humidity

95% at 40ºC (non-condensing)

Minimum Humidity

15% at 40ºC (non-condensing)

Maximum Altitude

3,000 meters (9,840 feet)

Location

For use indoors.

Storage Conditions

Storage Temperature

-20ºC to +70ºC

Non-Operating Maximum Humidity

90% at 65ºC (non-condensing)

Non-Operating Maximum Altitude

15,240 meters (50,000 feet)

General

Dimensions

The following dimensions exclude front and rear panel protrusions:
212.6 mm W x 88.5 mm H x 348.3 mm D (8.5 in x 3.5 in x 13.7 in)

Weight

Net

HP EPM-441A, 4.0 Kg (8.8 lb)

HP EPM-442A, 4.1 Kg (9.0 lb)

Shipping

HP EPM-441A, 7.9 Kg (17.4 lb)

HP EPM-442A, 8.0 Kg (17.6 ib)

Safety

Conforms to the following Product Specifications:

- EN61010-1: 1993/IEC 1010-1:1990+A1/CSA C22.2 No. 1010-1:1993
- EN60825-1: 1994/IEC 825-1: 1993 Class 1
- Low Voltage Directive 72/23/EEC

Remote Programming

Interface

HP-IB interface operates to IEEE 488.2.

Command Language

SCPI standard interface commands.

HP EPM-441A is HP 437B code compatible.

HP EPM-441A HP-IB Compatibilty

SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP1, DC1, DT1, C0

Non-Volatile Memory

Battery

Lithium Polycarbon Monoflouride, approximate lifetime 5 years at 25ºC.

2

Performance Tests

Introduction

The procedures in this chapter test the power meter's electrical performance using the specifications in Chapter 1 as the performance standards. All tests can be performed without access to the interior of the power meter. A simpler operational test is included in "Self Test" of the *User's Guide*.

Note

For valid performance tests, the following conditions must be met:

a. The power meter and test equipment must have a 30 minute warm-up for all specifications.

b. The line voltage for the power meter must be 85 to 264 Vac and the line frequency must be 47 to 63 Hz.

c. The ambient temperature must be 0^0 to 55^0C.

Equipment Required

Table 2-1 lists all the equipment required for the adjustments and performance tests. If substitutions must be made, the equipment used must meet the critical specifications.

Table 2-1: Required Equipment

Equipment Required	Model Number	Critical Specification	Usage[1]
Digital Multimeter	HP 3458A	Range 0 to 20 V Resolution 0.01 V	P and A
Range Calibrator	HP 11683A	Calibration Uncertainty ±0.25%	P and A
Frequency Counter	HP 5314A	Range 10 Hz to 50 MHz Resolution 1 Hz	P and A
Power Meter	HP 432A	Range 1 mW Transfer Accuracy 0.2%	P and A
Thermistor Mount	HP 478A Option H75 HP 478A Option H76	SWR<1.05 at 50 MHz Accuracy ±0.5% at 50 MHz	P and A
Power Sensor	HP E-series power sensor		P
30 dB Attenuator	HP 11807A *or* HP 8491A Option 030		P
Power Sensor Cable	HP 11730A		P and A

1. P = Performance Tests, A = Adjustments

Performance Test Record

Results of the performance tests may be tabulated in Table 2-6, “Performance Test Record,” on page 2-18. The Performance Test Record lists all of the performance test specifications and the acceptable limits for each specification. If performance test results are recorded during an incoming inspection of the power meter, they can be used for comparison during periodic maintenance. The test results may also prove useful in verifying proper adjustments after repairs are made.

Performance Tests

The performance tests given in this chapter are suitable for incoming inspection or preventive maintenance. During any performance test, all shields and connecting hardware must be in place.

The tests are designed to verify published power meter specifications. Perform the tests in the order given and record the data in Table 2-6 on page 2-18 and/or in the data spaces provided at the end of each procedure.

Calibration Cycle

This power meter requires periodic verification of performance to ensure that it is operating within specified tolerances. The performance tests described in this chapter should be performed once each year. Under conditions of heavy usage or severe operating environments, the tests should be more frequent. Adjustments that may be required are described in Chapter 3.

Test Procedures

It is assumed that the person performing the following tests understands how to operate the specified test equipment. Equipment settings, other than those for the power meter, are stated in general terms. It is assumed that the person will select the proper cables, adapters, and probes required for test setups illustrated in this chapter.

Zero Test

Specification

Electrical Characteristics	Performance Limits
Accuracy: Zero set (Digital settability of zero)	±0.0764 μW[1]

1. This performance limit is determined by the zero set specification of the power sensor used in the measurement plus the measurement noise. The range calibrator has a zero set specification of ±0.05 μW. The calibrator measurement noise specification is 110 nW at 16 averages. At 512 averages a noise multiplier of 0.24 is required, giving a measurement noise specification of 0.0264 μW (0.24x512).

Description

After the power meter is initially calibrated and zeroed, the change in the digital readout is monitored. This test also takes drift and noise into account, since drift, noise and zero readings cannot be separated.

Equipment

Range Calibrator ..... HP 11683A
Power Sensor Cable ..... HP 11730A

Test Setup

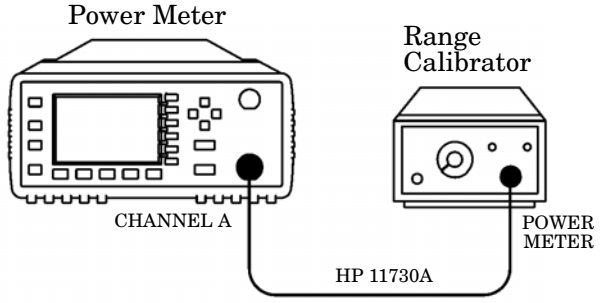


Figure 2-1: Zero Test Setup

Procedure

The following procedure should be performed for the Zero Test.

Note The procedure details the key presses required on the HP EPM-441A. For the HP EPM-442A the equivalent key presses should be performed on both channels.

1. Connect the equipment as shown in Figure 2-1.
2. Switch the power meter on.
3. Press (Preset Local) then `Confirm`.
4. Press (dBm/W), `W` for a reading in watts.
5. Set the range calibrator as follows:
   RANGE..... 3 µW
   POLARITY ..... NORMAL
   FUNCTION..... STANDBY
   LINE..... ON

Note When switching the range calibrator to STANDBY, allow enough time for the range calibrator to settle to its zero value before attempting to zero the power meter. This settling would appear on the power meter display as downward drift. When the drift has reached minimum, (typically less than 60 seconds), the range calibrator is settled.

6. On the power meter press (System Inputs), `Input Settings`, `Filter` select 512 from the pop up window then press `Enter`.
7. On the power meter press (Zero Cal), `Cal`. When the wait symbol disappears press `Zero`. Wait approximately 10 seconds for the wait symbol to disappear.
8. Wait 30 seconds then verify that the power meter's reading is within ±0.05 µW. Record the reading.

Table 2-2: Zero Test Results

Min	Channel A Actual Result	Channel B Actual Result (HP EPM-442A Only)	Max
-76.40 nW	_____	_____	+76.40 nW

Instrument Accuracy Test

Specification

Electrical Characteristics	Performance Limits
Accuracy	±0.5% or ±0.02 dB [1]

1. This performance limit does not include the corresponding sensor power linearity specification.

Description

The power meter accuracy is verified for various power inputs. The range calibrator is switched to provide these reference inputs.

Equipment

Range Calibrator ..... HP 11683A
Power Sensor Cable ..... HP 11730A

Test Setup

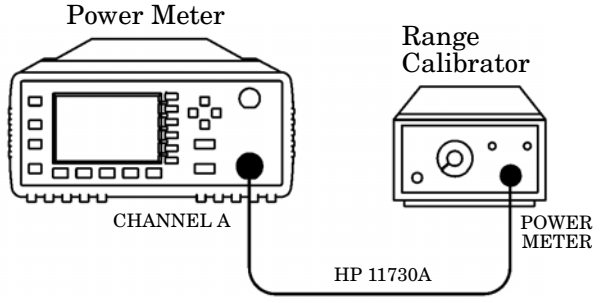


Figure 2-2: Instrument Accuracy Test Setup

Procedure

The following procedure should be performed for the Instrument Accuracy Test.

Note The procedure details the key presses required on the HP EPM-441A. For the HP EPM-442A the equivalent key presses should be performed on both channels.

1. Connect the equipment as shown in Figure 2-2.
2. Switch the power meter on.
3. Press (Preset Local) then `Confirm`.
4. Press (dBm/W), `W` for a reading in watts.
5. Set the range calibrator as follows:
   RANGE..... 3 µW
   POLARITY ..... NORMAL
   FUNCTION.....STANDBY
   LINE .....ON

Note When switching the range calibrator to STANDBY, allow enough time for the range calibrator to settle to its zero value before attempting to zero the power meter. This settling would appear on the power meter display as downward drift. When the drift has reached minimum, (typically less than 60 seconds), the range calibrator is settled.

6. On the power meter press (System Inputs), `Input Settings`, `Filter` select 512 from the pop up window then press `Enter`.
7. On the power meter press (Zero Cal), `Zero`. Wait approximately 10 seconds for the wait symbol to disappear. Verify that the display reads 0 ±0.05 µW.
8. Set the range calibrator's FUNCTION switch to CALIBRATE.
9. Set the range calibrator's RANGE switch to 1 mW.
10. Press `Cal` to calibrate the power meter.
11. Set the range calibrator's RANGE switch to the positions shown in Table 2-3 on page 2-9. For each setting, verify that the power meter's reading is within the limits shown.

Table 2-3: Instrument Accuracy Results

Range Calibrator Setting	Min[1]	Channel A Actual Results	Channel B Actual Results (HP EPM-442A only)	Max[1]
3 µW	3.100 µW	_____	_____	3.230 µW
10 µW	9.900 µW	_____	_____	10.10 µW
30 µW	31.40 µW	_____	_____	31.80 µW
100 µW	99.50 µW	_____	_____	100.5 µW
300 µW	0.314 µW	_____	_____	0.318 µW
1 mW	0.995 mW	_____	_____	1.005 mW
3 mW	3.141 mW	_____	_____	3.171 mW
10 mW	9.984 mW	_____	_____	10.08 mW
30 mW	31.63 mW	_____	_____	31.94 mW
100 mW	100.9 mW	_____	_____	101.8 mW

1. These performance limits are determined by the zero set specification of the power sensor used in the measurement plus the measurement noise.

Note The nominal outputs for the 3 µW, 30 µW, 300 µW, 3 mW, 10 mW, 30 mW and, 100 mW settings are 3.16 µW, 31.6 µW, 316 µW, 3.156 mW, 10.03 mW, 31.78 mW, and 101.3 mW respectively.

Note It is not necessary to check instrument accuracy in dBm. The power meter uses the same internal circuitry to measure power and mathematically converts watts to dBm.

Power Reference Level Test

Electrical Characteristics	Performance Limits	Conditions
Power Reference	1 mW	Internal 50 MHz oscillator factory set to ±0.7% traceable to National Institute of Standards and Technology (NIST).
Power Reference Accuracy	±1.9%	Worst case (power meter accuracy plus verification system error).
	±0.9%	RSS for one year.

Description

The power reference oscillator output is factory adjusted to 1 mW ±0.7%. This accuracy is achieved using a measurement system accurate to 0.5% (traceable to the National Institute of Standards and Technology) and allows for a transfer error of ±0.2% when making the adjustment.

If an equivalent measurement system is employed for verification, the power reference oscillator output can be verified to 1 mW ±1.9%. The 1.9% maximum error is made up of ±0.7% factory adjustment accuracy, ±0.5% worst case oscillator drift for one year, ±0.5% verification system error and ±0.2% transfer error.

If the Power Reference Oscillator Level Adjustment is carried out before this verification test is performed, the result obtained here will be more accurate.

The power reference oscillator can be set to ±0.7% using the same equipment and following the adjustment procedure. To ensure maximum accuracy in verifying the power reference oscillator output, the following procedure provides step by step instructions for using specified Hewlett-Packard test instruments of known capability. If equivalent test instruments are used, signal acquisition criteria may vary and reference should be made to the manufacturer's guidelines for operating the instruments.

Equipment

Test power meter ..... HP 432A
Thermistor Mount ..... HP 478A Option H75 or H76
Digital Voltmeter (DVM)..... HP 3458A

Test Setup

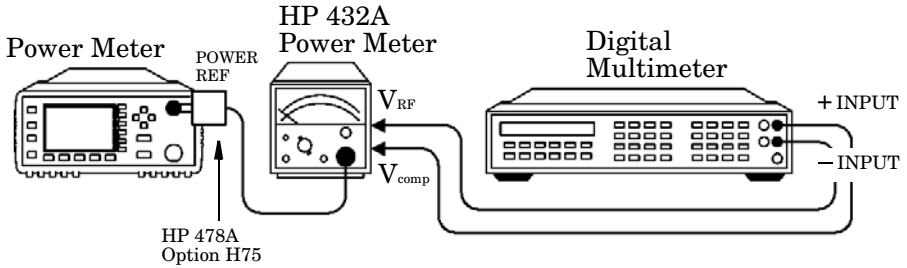


Figure 2-3: Power Reference Level Test Setup

Procedure

The following equation allows the Power Reference Oscillator power to be calculated by measuring the voltages V_0, V_1, V_{comp}, and the resistance R.

$$P_{meas} = \frac{2V_{comp}(V_1 - V_0) + V_0^2 - V_1^2}{4R(CalibrationFactor)}$$

The definitions of the terms in this equation are:

- V_0 is the voltage measured between V_{comp} and V_{RF} with no power applied and after the HP 432A has been zeroed.
- V_1 is the voltage measured between V_{comp} and V_{RF} with power applied. This power is approximately 1 mW.
- V_{comp} is the voltage between the HP 432A V_{comp} connector and chassis ground with power applied.
- R is the resistance of the mount resistor in the HP 432A power meter.
- Calibration Factor is the value of the thermistor mount at 50 MHz.

The following procedure should be performed to allow you to calculate P_{meas}.

Note The procedure details the key presses required on the HP EPM-441A. For the HP EPM-442A the equivalent key presses should be performed on both channels.

1. Set the DVM to measure resistance. Connect the DVM between the V_{RF} connector on the rear panel of the HP 432A and pin 1 on the thermistor mount end of the sensor cable. Verify that no power is applied to the HP 478A.
2. Round off the DVM reading to two decimal places and record this value as the internal bridge resistance (R) of the HP 432A (approximately 200 Ω).
   - R _____Ω
3. Connect the equipment as shown in Figure 2-3, ensuring that the DVM input leads are isolated from chassis ground.

Note Ensure that the HP 432A and the power meter under test have been powered on for at least 30 minutes before performing the following steps.

4. Press (Preset / Local) on the power meter.
5. Set the HP 432A RANGE switch to Coarse Zero. Adjust the front panel Course Zero control to obtain a zero meter indication.
6. Fine zero the HP 432A on the most sensitive range, then set the RANGE switch to 1 mW.
7. Set the DVM to measure microvolts. Connect the positive and negative input leads, respectively, to the V_{comp} and V_{RF} connectors on the rear panel of the test power meter.
8. Observe the reading on the DVM. If less than 400 μV, proceed to the next step. If 400 μV or greater, press and hold the test power meter Fine Zero switch and adjust the Coarse Zero control so that the DVM indicates 200 μV or less. Release the Fine Zero switch and proceed to the next step.
9. Round the DVM reading to two decimal places. Record this reading as V_0.
   - V_0 _____

10. Turn the power reference on by pressing
    - (Zero Cal), `Power Ref Off On` on the HP EPM-441A.
    - (Zero Cal), `Cal`, (More), `Power Ref Off On` on the HP EPM-442A.
11. Round the DVM reading to two decimal places. Record this reading as V_1.
    - V_1 _____
12. Disconnect the DVM negative input lead from the V_{RF} connector on the HP 432A. Reconnect it to the HP 432A chassis ground.
13. Observe the DVM reading. Record the reading as V_{comp}.
    - V_{comp} _____
14. Calculate the Power Reference Oscillator power using the following equation:

$$P_{meas} = \frac{2V_{comp}(V_1 - V_0) + V_0^2 - V_1^2}{4R(CalibrationFactor)}$$

15. Verify that P_{meas} is within the limits shown in Table 2-4. Record the reading.

Table 2-4: Power Reference Level Result

Min	Channel A Actual Result	Channel B Actual Result (HP EPM-442A Only)	Max
0.981 mW	_____	_____	1.019 mW

HP E-Series Power Sensor Interface Test

The HP E-series power sensors have their sensor calibration tables stored in EEPROM which enables the frequency and calibration factor data to be downloaded automatically by the power meter. The frequency and calibration factor data have checksums which are compared with the data downloaded by the power meter. For the HP EPM-442A dual channel power meter, this test should be performed on both channels.

Procedure

1. When there is no power sensor connected to the Channel A input the message "`No Sensor`" ("`No Sensor ChA`" on the HP EPM-442A) appears on the measurement window.
2. Connect the HP E-series power sensor to the power meter's Channel A input. The message "`Reading Sensor ChA`" appears. When all the data is downloaded this message disappears and a reading is displayed on the measurement window. If the download fails, a warning message and error flag are displayed on the front panel. Also, SCPI error message "-310, System Error" is generated.
3. For the HP EPM-442A repeat these steps for Channel B.

HP E-Series Power Sensor Functional Test

Description

This test verifies that the meter/sensor combination can make RF measurements.

The HP E-series power sensors operate over a 90 dB dynamic range (-70 to +20 dBm). However, since there is an amplifier in these power sensors, the voltages presented to the power sensor connector are always within the range of voltages available from the HP 11683A range calibrator.

Equipment

Power Sensor Cable ..... HP 11730A
Reference Attenuator ..... HP 11708A
HP E-series power sensor

Procedure

To complete the Functional Test the following procedure should be performed.

Note The procedure details the key presses required on the HP EPM-441A. For the HP EPM-442A the equivalent key presses should be performed on both channels.

1. Connect the equipment as shown in Figure 2-4.

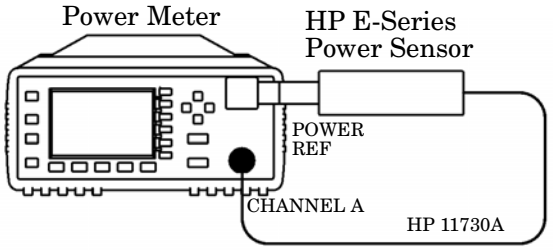


Figure 2-4: Sensor Functional Test Setup

2. Press (Preset / Local).
3. On the power meter press (Zero / Cal), `Zero`. Wait approximately 10 seconds for the wait symbol to disappear. Verify that the display reads 0 ±50 pW.
4. Press `Cal` to calibrate the power meter.
5. Turn the power reference on by pressing
   - (Zero / Cal), `Power Ref Off On` on the HP EPM-441A.
   - (Zero / Cal), `Cal`, (More), `Power Ref Off On` on the HP EPM-442A.

6. Connect the 30 dB attenuator as shown in Figure 2-5.

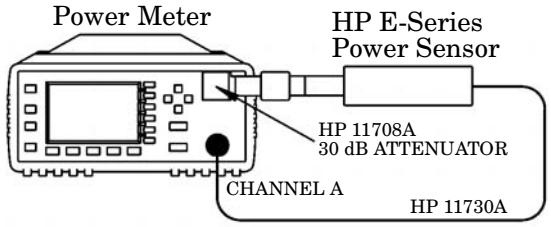


Figure 2-5: Sensor Functional Test Setup with Attenuator

7. Press System Inputs, `Input Settings`, More, and select `Range` to "`LOWER`". This switches to the power sensor's low range.
8. Verify that the display reads -30 dBm ±1 dB. Record the reading.
9. Press `Range` and set to "`UPPER`". This switches to the power sensor's upper range.
10. Verify that the display reads -30 dBm ±1 dB. Record the reading.
11. Press `Range` and set to "`LOWER`".
12. Disconnect the 30 dB attenuator and reconnect as shown in Figure 2-4.
13. Verify that an overload error is displayed on the status line at the top of the power meter's display.
14. Press `Range` and set to "`UPPER`".
15. Verify that the display reads 0 dBm ±1 dB. Record the reading.

Table 2-5: Functional Test Result

Test	Channel A Overload Error	Channel B Overload Error (HP EPM-442A Only)
Low Range, 30 dB pad		
Upper Range, 30 dB pad		
Low Range, no pad		
High Range, no pad		

Performance Test Record

Model HP EPM-441A/442A Power Meter

Tested by _____

Serial Number _____

Date _____

Table 2-6: Performance Test Record

Test	Min Result	Channel A Actual Result	Channel B Actual Result	Max Result
Zero Test	–76.40 nW			+76.40 nW
Instrument Accuracy				
3 µW	3.100 µW	_____	_____	3.230 µW
10 µW	9.900 µW	_____	_____	10.10 µW
30 µW	31.40 µW	_____	_____	31.80 µW
100 µW	99.50 µW	_____	_____	100.5 µW
300 µW	0.314 mW	_____	_____	0.318 mW
1 mW	0.995 mW	_____	_____	1.005 mW
3 mW	3.141 mW	_____	_____	3.171 mW
10 mW	9.984 mW	_____	_____	10.08 mW
30 mW	31.63 mW	_____	_____	31.94 mW
100 mW	100.9 mW	_____	_____	101.8 mW
Power Reference				
P_{meas}	0.981 mW	_____	_____	1.019 mW
Interface Test	Pass/Fail	_____	_____	Pass/Fail
Functional Test				
Low Range, 30 dBm pad	Pass/Fail	_____	_____	Pass/Fail
Low Range, 30 dBm pad	Pass/Fail	_____	_____	Pass/Fail
Low Range, no pad	Pass/Fail	_____	_____	Pass/Fail
Upper Range, no pad	Pass/Fail	_____	_____	Pass/Fail

3

Adjustments

Introduction

This chapter describes adjustments and checks which ensure proper performance of the power meter. Adjustments are not normally required on any fixed periodic basis, and normally are performed only after a performance test has indicated that some parameters are out of specification. Performance tests should be completed after any repairs that may have altered the characteristics of the power meter. The test results will make it possible to determine if adjustments are required. Allow 30 minutes for the power meter to warm up, and then remove the cover, for access to the test and adjustment points.

To determine which performance tests and adjustments to perform after a repair, see “Post-Repair Adjustments”, on page 3-3.

Safety Considerations

This warning must be followed for your protection and to avoid damage to the equipment being used.

WARNING **Adjustments described in this chapter are performed with power applied to the instrument and with protective covers removed. Maintenance should be performed only by trained personnel who are aware of the hazards involved. When the maintenance procedure can be performed without power, the power should be removed.**

Equipment Required

The adjustment procedures include a list of recommended test equipment. The test equipment is also identified on the test setup diagrams.

Post-Repair Adjustments

Table 3-1 lists the adjustments related to repairs or replacement of any of the assemblies.

Table 3-1: Post Repair Adjustments, Tests, and Checks

Assembly Replaced	Related Adjustments, Performance Tests or Self Tests
A1 Power Supply	Self Test
A2 Processor Assembly	Frequency and Level Adjustments, Power Reference Level Test, Display Brightness and Contrast Adjustment.
A3 Front Panel Assembly	Instrument Accuracy Test, Display Brightness and Contrast Adjustment.
A4 Interface Assembly	All automated Tests
A5 Daughter Assembly	Instrument Accuracy Test
A6 Measurement Assembly	Zero Test, Instrument Accuracy Test
W1 or W2 Power Sensor Cable	Instrument Accuracy Test, Zero Test
BT1 Battery	Battery Self Test
Power Reference Cable Kits	Power Reference Level Test

Power Reference Oscillator Frequency Adjustment

Note

Adjustment of the power reference oscillator frequency may also affect the output level of the oscillator. Therefore, after the frequency is adjusted to 50.0 ±0.5 MHz, the output level should be checked as described in "Power Reference Oscillator Level Adjustment", on page 3-6.
The power reference oscillator frequency is a nominal specification.

Description

Variable inductor A2L9 is adjusted to set the power reference oscillator output frequency to 50.0 ±0.5 MHz. This frequency is a supplemental characteristic.

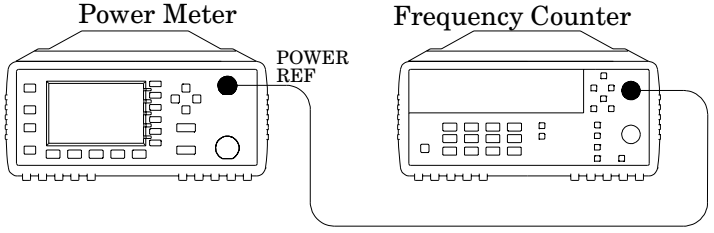


Figure 3-1: Adjustment Setup

Equipment

Frequency Counter..... HP 5314A

Procedure

1. Ensure that the power meter has been powered on for at least 30 minutes before making any measurements.
2. Connect the equipment as shown in Figure 3-1. Set up the counter to measure frequency.

3. Turn the power reference on by pressing
   - (Zero Cal), `Power Ref Off On` on the HP EPM-441A.
   - (Zero Cal), `Cal`, (More), `Power Ref Off On` on the HP EPM-442A.
4. Observe the reading on the frequency counter. If it is 50.0 ±0.5 MHz, no adjustment of the power reference oscillator frequency is necessary. If it is not within these limits, adjust the power reference oscillator frequency as described in step 5 and step 6.
5. Remove the power meter cover.
6. Adjust A2L9 to obtain a 50.0 ±0.5 MHz indication on the frequency counter. Refer to Figure 3-2 for the position of A2L9.

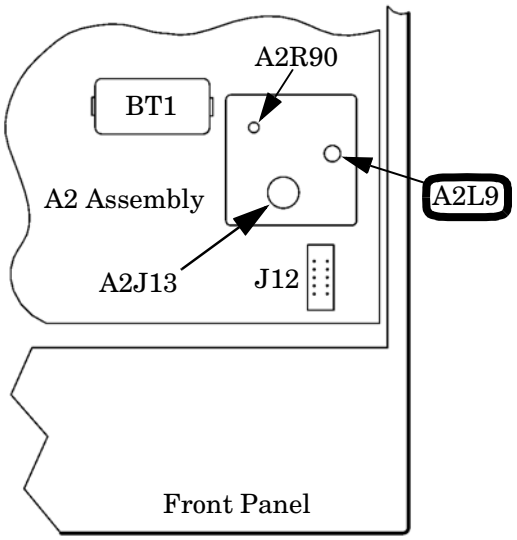


Figure 3-2: A2L9 Adjustment Location

Power Reference Oscillator Level Adjustment

Description

The power reference oscillator is factory adjusted to 1.0 mW ±0.7%. This is done using a special measurement system accurate to 0.5% traceable to the National Institute of Standards and Technology (NIST) and allowing for a 0.2% transfer error. To ensure maximum accuracy in re-adjusting the power reference oscillator, the following procedure provides step-by-step instructions for using specified Hewlett-Packard instruments of known capability. If equivalent instruments are used, signal acquisition criteria may vary and reference should be made to the manufacturer's guidelines for operating the equipment.

Note The power meter may be returned to the nearest HP office to have the power reference oscillator checked and/or adjusted.

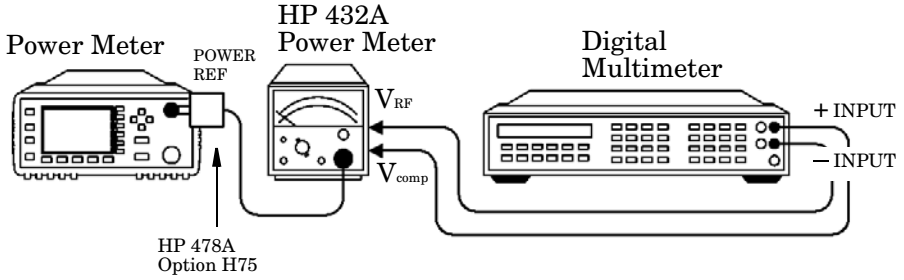


Figure 3-3: Adjustment Setup

For this adjustment the following mathematical assumptions are made:

Equation 1:

$$P_{meas} = \frac{2V_{comp}(V_1 - V_0) + V_0^2 - V_1^2}{4R(CalibrationFactor)}$$

can be manipulated to give equation 2:

$$V_1 = V_{comp} + V_0 - \sqrt{V_{comp}^2 - (10)^{-3}(4R)(CalibrationFactor)}$$

by using the following assumptions:

$$V_0^2 - V_1^2 = -(V_1 - V_0)^2$$

The error in doing this is:

$$-(V_1^2 + V_0^2 - 2V_1V_0) - (V_0^2 - V_1^2) = -2V_0^2 + 2V_1V_0 = 2V_0(V_1 - V_0)$$

So if $2V_0(V_1 - V_0) \ll 2V_{comp}(V_1 - V_0)$, that is, $V_0 \ll V_{comp}$ then the error can be ignored. In practice $V_{comp} \sim 4Volts$ and $V_0 < 400\mu V$. The error is less than 0.01%.

By substituting equation 3 into equation 1 and manipulating the result you get:

$$0 = (V_1 - V_0)^2 - 2V_{comp}(V_1 - V_0) + 4(10^{-3})R(CalibrationFactor)$$

This quadratic can be solved to give equation 2.

The definitions of the terms in equation 2 are:

- V_0 is the voltage measured between V_{comp} and V_{RF} with no power applied and after the HP 432A has been zeroed.
- V_1 is the voltage measured between V_{comp} and V_{RF} with power applied. This power is approximately 1 mW.
- V_{comp} is the voltage between the HP 432A V_{comp} connector and chassis ground with power applied.
- R is the resistance of the mount resistor in the HP 432A power meter.
- Calibration Factor is the value of the thermistor mount at 50 MHz.

Equipment

Test power meter ..... HP 432A
Thermistor Mount ..... HP 478A Option H75
Digital Voltmeter (DVM)..... HP 3456A

Procedure

Note The procedure details the key presses required on the HP EPM-441A. For the HP EPM-442A the equivalent key presses should be performed on both channels.

1. Set up the DVM to measure resistance. Connect the DVM between the V_{RF} connector on the rear panel of the HP 432A and pin 1 on the thermistor mount end of the sensor cable. Verify that no power is applied to the HP 478A
2. Round off the DVM reading to two decimal places and record this value as the internal bridge resistance (R) of the test power meter (approximately 200 Ω).
   - R (Internal Bridge Resistance)_____Ω
3. Connect the equipment as shown in Figure 3-3. The leads should be isolated from ground. Ensure that the power reference oscillator is off. Ensure that both the power meter under test and the HP 432A have been powered on for at least 30 minutes before proceeding to the next step.
4. Set the HP 432A range switch to coarse zero and adjust the front panel coarse zero control to obtain a zero meter indication.
5. Fine zero the HP 432A on the most sensitive range, then set the range switch to 1 mW.

Note Ensure that the DVM input leads are isolated from chassis ground when performing the next step.

6. Set up the DVM to measure microvolts.
7. Connect the positive and negative input leads, respectively, to the V_{comp} and V_{RF} connectors on the rear panel of the HP 432A.

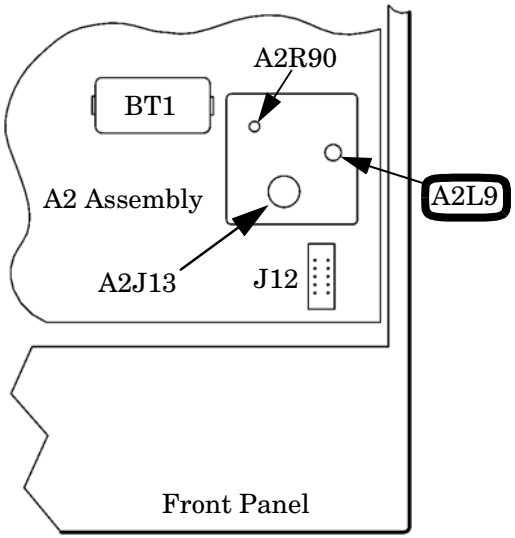
8. Observe the reading on the DVM. If less than 400 μV, proceed with the next step. If 400 μV or greater, press and hold the HP 432A fine zero switch and adjust the coarse zero control so that the DVM indicates 200 μV or less. Then release the fine zero switch and proceed to the next step.
9. Round off the DVM reading to the nearest microvolt and record this value as V_0.
   - V_0_____μV
   - Disconnect the DVM negative input lead from the V_{RF} connector on the test power meter and reconnect it to chassis ground.

10. Turn the power reference on by pressing
    - (Zero Cal), `Power Ref Off On` on the HP EPM-441A.
    - (Zero Cal), `Cal`, (More), `Power Ref Off On` on the HP EPM-442A.
11. Record the reading on the DVM to two decimal places. This is V_{comp}.
    - V_{comp} _____V
12. Reconnect the negative lead to the V_{RF} connector on the rear panel of the HP 432A. The DVM is now set up to measure V_1 which represents the power reference oscillator output level.
13. Calculate the required value of V_1 using equation 2.

$$V_1 = V_{comp} + V_0 - \sqrt{V_{comp}^{2} - (10)^{-3}(4R)(CalibrationFactor)}$$

14. Remove the power meter's cover and adjust A2R90 until the DVM indicates the calculated value of V_1. Refer to Figure 3-4 for the position of A2R90.

Figure 3-4: A2R90 Adjustment Location



Measurement Uncertainty

When calculating measurement uncertainty the significant multimeter uncertainty parameters are for V_{comp}, V_1-V_0 and R. Other uncertainties which should be included are:

- Maths Assumptions: ±0.01%
- Effective Efficiency Calibration: ±0.05%
- Mismatch Uncertainty with Source and Mount: ±0.1%
- SWR: ≤1.05

These values are typical.

Display Brightness and Contrast Adjustment

Introduction

The following procedure should be performed whenever a front panel assembly or processor assembly are replaced.

The brightness is controlled automaticaly after executing the `Set Brightness` softkey, located under the `Service` softkey menu.

Note The contrast adjustment is subjective and varies according to individual user requirements.

Procedure

1. Access the `Display` softkey menu and use the ↑◑ softkey to increase the contrast, or the ↓◑ softkey to decrease the contrast of the display.
2. When the desired display contrast level is obtained, press the `Set Contrast` softkey, located under the `Service` softkey menu.

4

Theory of Operation

Introduction

This chapter describes how each of the power meter's assemblies operate. A block diagram is included at the end of the chapter giving you an overall view of the power meter's operation.

A1 Power Supply

The power supply is a 40 W, 47 to 63 Hz switching power supply which produces three voltages (+5 V, +12 V and -12 V).

The mains fuse can be changed easily since it is located in the line input module on the power meter's rear panel (HP Part Number 2110-0957). The fuse holder contains a spare fuse as standard on shipment.

In addition there is also a fuse on the power supply assembly (HP Part Number 2110-0957). However, a transient suppressor is fitted to the line input module so that any mains transient blows the line module fuse before the power supply fuse. If the power supply fuse blows there is a fault within the power meter.

A2 Processor Assembly

The processor assembly contains the microcontroller and associated circuits, the power-on/ standby control and switching, the 1 mW reference calibrator, the recorder output, and the front panel drivers. It provides that platform on which the power meter can run, facilitating the system inputs and outputs.

Regulated DC voltages at +12 V, -12 V and +5 V are converted by the A1 power supply assembly when the AC mains is attached to the rear. The DC voltages are connected and distributed to the rest of the system by circuits on the processor assembly. When the ⏻ key on the front panel is pressed a bistable latch changes state. This, in turn, applies the correct gate voltages to turn on three MOSFET switches, which connects the power supply unit voltages to the distributed power buses. The bistable latch is connected to a permanent power-supply which has the backup of battery power when AC mains is removed from the power meter. The +12 V supply is used to power the fan. This is filtered to decouple it from the rest of the system.

The reference oscillator has a 50 MHz oscillator circuit with automatic level control (ALC). The oscillator output is level detected and that level is compared to a temperature stable precision reference voltage. This comparison produces an error signal that gives negative feedback control of the oscillator output power. The frequency and power level of the calibrator are factory set to provide a 50 MHz 1 mW transfer standard. The precision reference voltage and the ALC control signal are both measured in the calibrator self test. The calibrator is switched on or off using a signal from the microcontroller. The front panel LED indicator is switched with a separate microcontroller signal.

The recorder is a 12 bit DAC driven by the microcontroller. The DAC output is buffered, filtered and scaled to give a 1 V full scale output with a nominal 1 kΩ output impedance.

Circuitry for the keyboard driver includes some damage protection, but it is basically a direct connection from the keypad row and column matrix to the microcontroller's control lines. Three LEDs on the front panel are illuminated under the following conditions:

LED	+12 V	+5 V	ref_led_off
Standby	Active	Not Active	-
On	Active	Active	-
Power Ref	Active	Active	Active

The LCD controller on the A3 front panel assembly is configured as a memory mapped peripheral, and as such requires only to be fed with the appropriate address, data and control lines from the microcontroller circuits. The bias voltage for the LCD is produced by a DC to DC converter that takes the +5 V (DIST) voltage and converts that to a nominal +21 V. The DC to DC converter is adjusted by a combination of the contrast control signal from the microcontroller and the temperature sense voltage that is generated on the A3 front panel assembly. The temperature sense voltage helps to compensate for the normal variation of LCD contrast with temperature. Current to the LCD's LED backlight array is sourced from a constant current circuit that compensates for variation in LED knee voltage. A control input to this circuit from the front panel temperature sense voltage allows for de-rating of the maximum LED current at high operating temperatures. A control input from the microcontroller allows the optimum backlight brightness to be factory set. The temperature sense voltage, LED current and LCD bias voltage are all measured at self test.

An analog multiplexer provides means by which several diagnostic points can be switched to the A6 measurement assembly(s) for analogue to digital conversion. The microcontroller uses this function to perform self test.

A6 measurement assembly(s) to microcontroller communication is conducted on a serial interface bus, the Internal Serial Bus (ISB). The ISB is connected to the bi-directional serial port on the microcontroller via buffers. The system clock and some control signals are connected to the measurement modules. The measurement module interface is completed with the distribution of switched and direct power (+12 V, -12 V and +5 V).

The microcontroller circuits that control all the above functions, and provide platform for the system software to run on, comprise the microcontroller itself, memory, and clock and logic circuits. The logic circuits have the function of ensuring the correct sequencing and decoding

of the control signals for the various peripherals. The crystal oscillator clock circuit is buffered and distributed to the A4 interface assembly and the A5 daughter assembly. The program memory for the microcontroller is FLASH EEPROM to allow for in-circuit programming. The static RAM is split into volatile and non-volatile blocks, with the power for the non-volatile RAM being connected to the permanent (battery backed) power supply.

A3 Front Panel Assembly

The front panel assembly is made up of a liquid crystal display (LCD), a keypad and, depending on the power meter option, a power reference cable assembly and a sensor cable assembly(s).

There are two inputs to the front panel assembly:

- the flex circuit from connector A2J4 of the processor assembly which controls the keypad.
- the ribbon cable from A2J3 of the processor assembly which controls the LCD display.

The power meter self tests contain display tests. These are accessed by pressing System Inputs, More, `Service`, `Self Test`, `Individual`, `Display`.

A4 Interface Assembly

The interface assembly contains the circuitry required for remote control of the power meter. This assembly supports the HP-IB interface with a protocol controller integrated circuit and two physical interface buffers. The assembly is connected to data, address, and control signals from the A2 processor assembly. The system clock from the A2 processor assembly is divided by four to provide the HP-IB controller integrated circuit's clock signal.

The interface assembly also provides a filtered path for the recorder output signal.

A5 Daughter Assembly

The daughter assembly is loaded vertically into the A2 processor assembly. It contains two slotted post connectors. Depending on whether you have an HP EPM-441A or an HP EPM-442A power meter, either one or two of these connectors are used respectively for the A6 measurement assembly(s).

A6 Measurement Assembly

There is one measurement assembly in the HP EPM-441A and two in the HP EPM-442A.

The measurement assembly amplifies and converts the chopped AC signal produced by the power sensor (either HP 8480 series power sensors or HP E-series power sensors) into a 32 bit digital word. This digital word is proportional to the input RF power level applied to the power sensor. The measurement assembly also measures the sensor resistor voltage to detect whether a power sensor is present. If a power sensor is connected it determines the model, and whether it's connected to the front or rear panel. This assembly produces the differential drive signal for the power sensor's chopper. When an HP E-series power sensor is present this assembly converts and corrects the power sensor's temperature dependent voltage.

With reference to the block diagram at the end of this chapter, the chopped AC input signal is amplified by the input amplifier. This operational amplifier in combination with a single bipolar transistor in the power sensor, produce a feedback amplifier which has a gain of approximately 500. The "Feedback" line shown sets the gain and also biases the transistor. The differential amplifier removes any common mode noise or interference. It uses a special ground wire ("Sensor Ground"), connected close to the RF bulkhead in the power sensor as it's second input.

The band pass filter represents the filtering action of the input amplifier. When the power meter is working with an HP E-series power sensor the equalizer is switched on to reduce the high pass cut off frequency of the input amplifier. This improves the settling time in fast mode operation.

The output of the equalizer is split into two paths. One path is amplified by a gain of 100. Both signals are each converted to digital words by the dual analog to digital converter (ADC). The ADC's sampling rate is set to a frequency 200 times above the chop rate for the HP 8480 series power sensors and 100 times above the chop rate for the HP E-series power sensors.

The Digital Signal Processor (DSP) converts the chopped signals into digital words proportional to the input level. It compares both levels, calibrates the gain and decides which level is output to the host processor (after additional filtering) via the "Internal Serial Bus".

The DSP chip controls the logic which sets the chopper driver voltage and frequency control. For the:

- HP 8480 series power sensors this is 0 V and -10 V at 217 Hz.
- HP E-series power sensors this is +7 V and -3 V at 434 Hz.

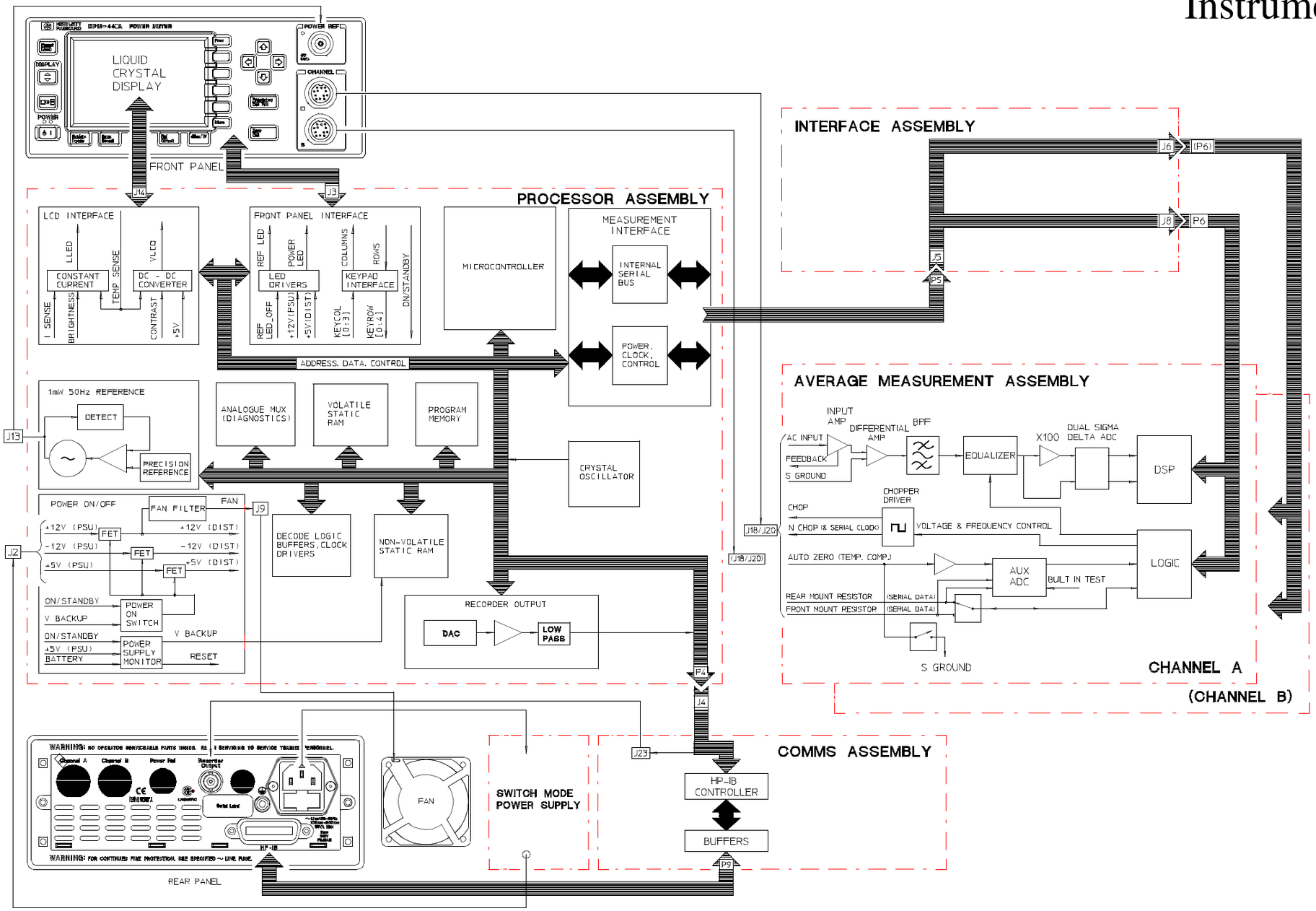
The DSP also controls logic to allow the AUX ADC to measure a number of voltages, and when requested, send the relevant data to the host processor. The AUX ADC digitizes a voltage which is produced by the HP E-series power sensors and is proportional to temperature. This voltage is required for temperature compensation. This AUX ADC also tests the sensor resistor wires to check sensor continuity. Lastly, use is made of this AUX ADC for the power meter's self test of both the measurement assembly and the A2 processor assembly. The results are reported back to the A2 processor assembly via the "Internal Serial Bus".

The HP E-series power sensors have built in serial EEPROM and range switching which is controlled or accessed via the measurement assembly. The "N-Chop" sensor wire used by the HP 8480 series power sensors doubles as a serial clock and the sensor resistor line doubles as a bi-directional serial data line. The "Auto Zero" line is also used as a serial bus enable control.

The wire labelled "Auto Zero" is grounded to the "Sensor Ground" line when an HP 8480 series power sensor is used. Autozeroing is accomplished without the need for this signal in the power meter.

All clocks are derived from the 16.67 MHz system clock which is generated on the A2 processor assembly and distributed on the A5 daughter assembly.

Instrument Block Diagram



5

Replaceable Parts

Introduction

This chapter contains details of some of the higher level components and assemblies which can be ordered from Hewlett-Packard. It also details how to assemble and disassemble the power meter for repair.

To order parts contact your local Hewlett-Packard Sales and Service Office.

To return your power meter for servicing at a qualified service center refer to “Contacting Hewlett-Packard” in Chapter 2 of the *User’s Guide*.

Assembly Part Numbers

Reference Designator	Description	HP Part Number	Check Digit
A1	Power Supply Assembly	0950-2649	2
A2	Processor Assembly	E4418-60001	2
A301	Front Panel Assembly for: HP EPM-441A and HP EPM-441A Option 002	E4418-69017	8
A302	Front Panel Assembly for: HP EPM-441A Option 003	E4418-69018	9
A303	Front Panel Assembly for: HP EPM-442A and HP EPM-442A Option 002	E4419-69019	1
A304	Front Panel Assembly for: HP EPM-442A Option 003	E4419-69020	4
A4	Interface Assembly	E4418-60004	5
A5	Daughter Assembly for: HP EPM-441A	E4418-60002	3
	Daughter Assembly for: HP EPM-442A	E4419-60002	4
A6	Measurement Assembly	E4418-60003	4
A7	Fan Assembly	E4418-61004	7
BT1	Battery	1420-0338	0
MP1	Bail Handle	34401-45011	9
MP2	Front Bumper	34401-86011	5
MP3	Rear Bumper	34401-86012	6
MP4	Outer Cover	E4418-00009	4
MP5	Rear Bezel	E4418-20008	5

Reference Designator	Description	HP Part Number	Check Digit
W1	Channel A sensor cable Assy	E4418-61009	2
W2	Channel B sensor cable Assy (HP EPM-442A only)	E4418-61009	2
W3	Recorder Output Cable Assy	E4418-61015	0
Front Power Reference Cable Kit		E4418-61811	4
Rear Power Reference Cable Kit		E4418-61813	6

Front Panel Connector Repair

The front panel assembly is an exchange assembly. However, if front panel sensor cables or power reference cables are faulty they should be replaced by ordering the appropriate kit and following the assembly/disassembly procedure. The instrument accuracy test should then be carried out to verify the functionality of the new part.

Firmware Upgrades

The power meter's firmware can be upgraded using a 300 or 700 series Unix workstation or a PC. The current version of firmware can be accessed by HP Service Centers using the World Wide Web. An executable file on the Unix workstation is also required.

To determine the firmware version in your power meter, press:

- System Inputs, More, `Service`, `Version`.

Contact your local Service Center if you require a firmware upgrade. Refer to "Sales and Service Offices", on page -ix for details of your local Service Center.

Downloading Firmware

Instrument Firmware should be downloaded after the processor board is replaced. Firmware can be accessed by HP Service Centers using the World Wide Web.

Assembly and Disassembly Guidelines

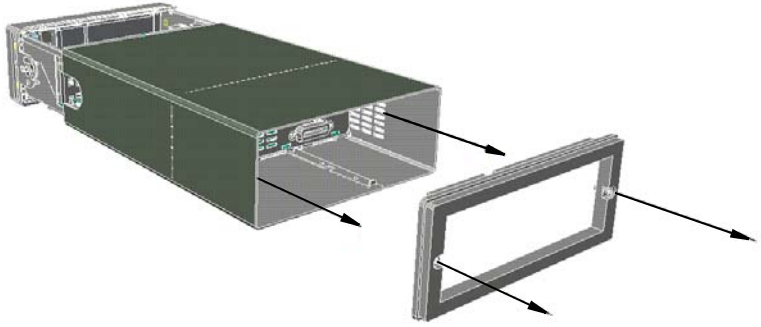
The guidelines in this section describe the removal and replacement of the major assemblies in the HP EPM-441A and HP EPM-442A power meters.

Once an assembly has been replaced, refer to "Post-Repair Adjustments", on page 3-3 to ensure that the correct performance tests and adjustments are carried out.

WARNING **Refer to the safety symbols on the power meter and "Equipment Operation", on page -v before operating this power meter with the cover removed. Failure to comply with the safety precautions can result in severe or fatal injury.**

WARNING **Before carrying out any assembly or disassembly of the power meter ensure that you disconnect the power cord. Even with the power meter switched off there are potentially dangerous voltages present on the power supply assembly.**

Removing the Power Meter Cover

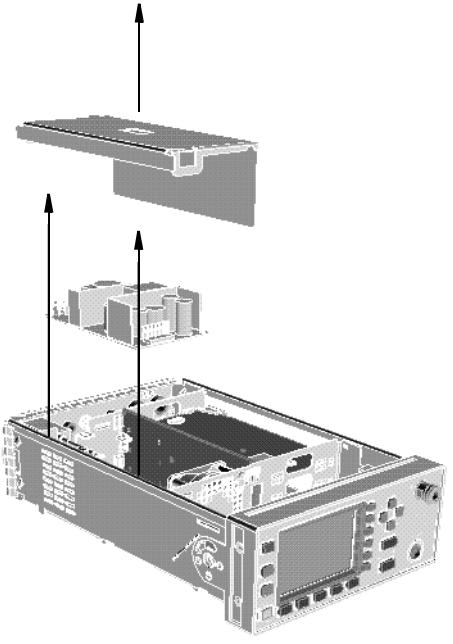


When replacing the power meter cover retighten the captive screws in the rear bezel using a 9 lb/in T15 screw driver.

Removing the A1 Power Supply Assembly

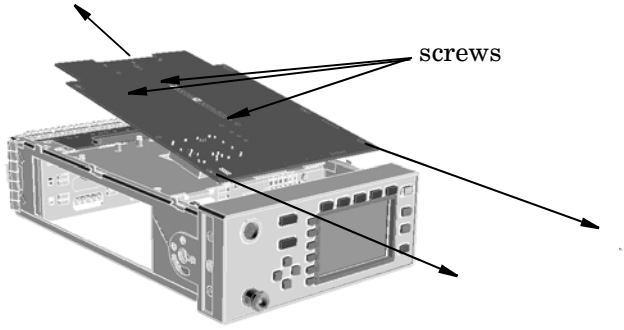
1. Remove the power supply cover by lifting it out.
2. Disconnect the line input module from the chassis and power supply assembly.
3. Disconnect the cable assembly from the power supply which connects to the A2 processor assembly.
4. Unscrew the power supply assembly and lift out the power supply. (When replacing these screws use a 9 lb/in T15 screw driver.)

WARNING **When replacing the power supply unit in the power meter ensure that all earth wiring is reconnected. There are two terminals to check, the first is the force fit connector to the power supply unit itself and the second a closed loop terminal bonded to the chassis with an M3.5 machine screw (use a 9 lb/in T15 screw driver). All the protective earth wiring can be identified by the insulation color green with a yellow stripe.**



Removing the A2 Processor Assembly

1. Remove the A5 daughter and A6 measurement assemblies as described on page 5-11.
2. Move the A2 plastic support bracket to its forward position using the two side levers, then disconnect the front panel keypad and front panel LCD cables from the A2 assembly.
3. Disconnect the following cables from the A2 processor assembly:
   - power reference semi-rigid
   - fan connector
   - power supply connector
4. Turn the power meter upside down and remove the three screws as shown. (When replacing these screws use a 6 lb/in T10 screw driver.)
5. Push the A2 processor assembly towards the front panel to release it from the 50-pin connector. Lift it upwards to remove.



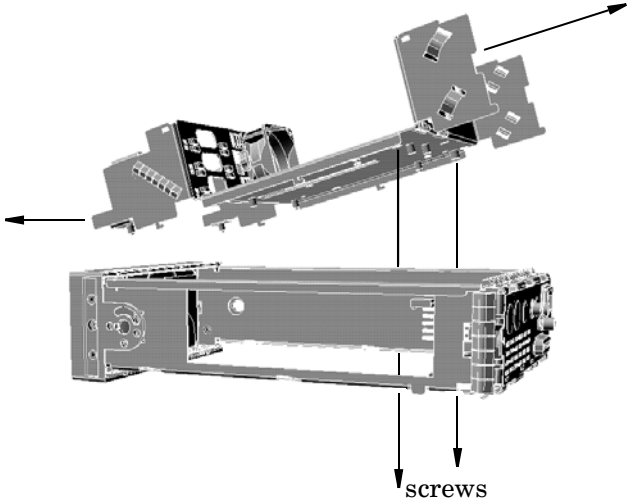
Note When re-assembling the processor board, ensure the A2 plastic support bracket is returned to its locked position.

Note After replacing a processor board, the display brightness and contrast must be adjusted. See Chapter 3 “Adjustments”.

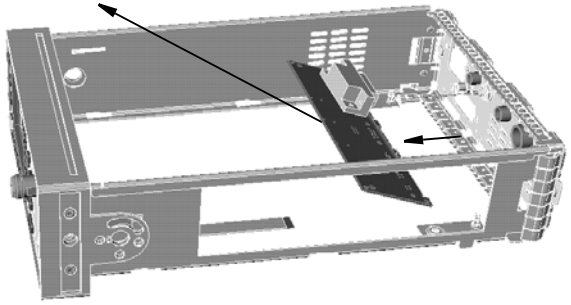
Note Firmware should be downloaded to the instrument after the processor board is replaced. Refer to “Downloading Firmware”, on page 5-6.

Removing the A4 Interface Assembly

1. Remove the A2 processor, A5 daughter and A6 measurement assemblies as shown on page 5-9 and page 5-11.
2. Disconnect the line power module from the A1 power supply and the chassis.
3. Disconnect the earth wire screw. (When replacing this screw use a 9 lb/in T15 screw driver.)
4. Remove the two screws on the underside of the deck assembly then remove the assembly by sliding forward and tilting up from the rear. (When replacing these screws use a 21 lb/in T15 screw driver.)



5. Unscrew the HP-IB connector from the rear panel. (When replacing these screws use a 6 lb/in 9/32 in socket.)
6. Disconnect the Recorder Output cable.
7. Lift the A4 interface assembly from the two standoffs and slide it out.



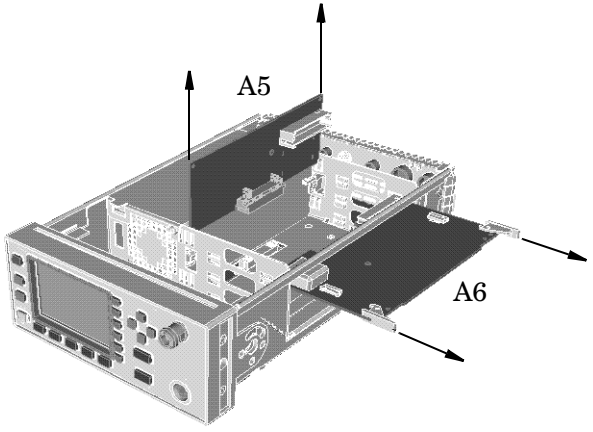
Removing the A5 Daughter or A6 Measurement Assemblies

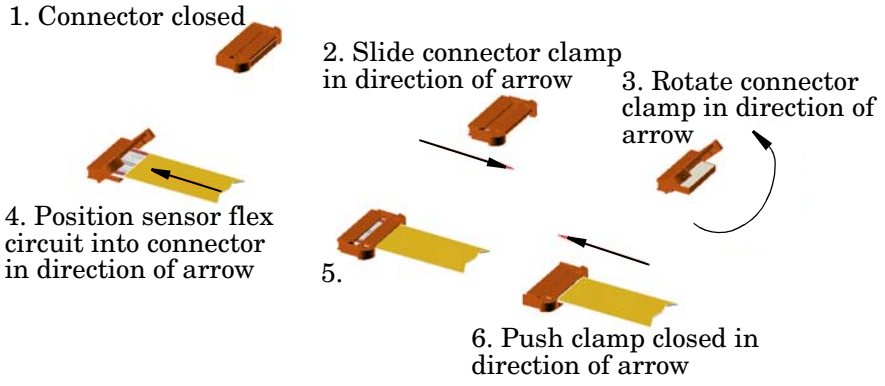
1. Disconnect the flex circuit from measurement assembly.

Note Care should be taken when disconnecting the flex circuit from the measurement assembly.

The flex circuit assembly is released by pushing the connector tab forward and lifting.
To replace the flex circuit, loop it as shown on page 5-16, and connect the flex circuit as shown in the figures below.

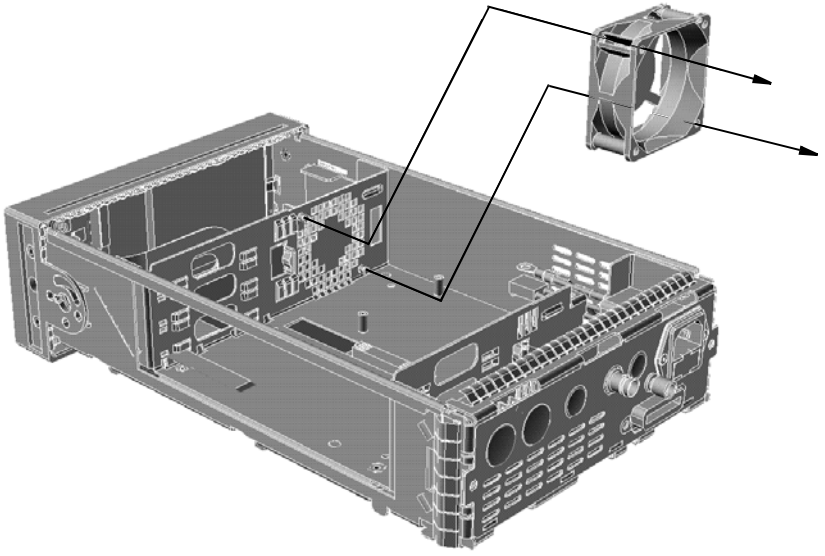
2. Slide out the measurement assembly from the side of the power meter.
3. The daughter assembly is removed vertically.




1. Connector closed
2. Slide connector clamp in direction of arrow
3. Rotate connector clamp in direction of arrow
4. Position sensor flex circuit into connector in direction of arrow
5.
6. Push clamp closed in direction of arrow

Removing the A7 Fan Assembly

1. Remove the A1 power supply assembly as shown on page 5-8.
2. Remove the pins which attach the fan to the chassis.
3. Remove the fan cable connector from the A2 processor assembly to release the fan.

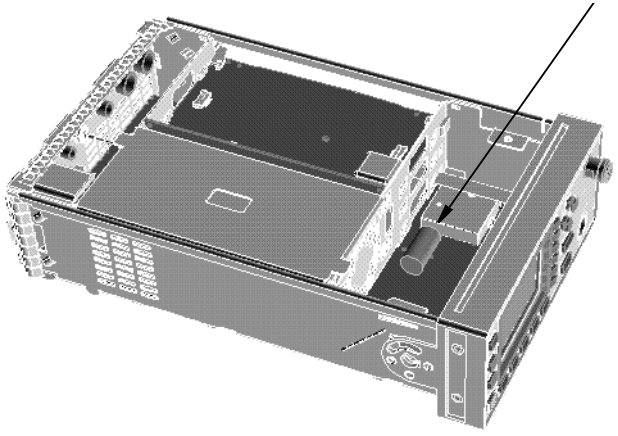


Removing the Power Meter Battery (BT1)

1. Remove the A2 processor assembly as described on page 5-9.
2. Remove the A2J1 link to disconnect the battery from the rest of the circuitry.
3. Verify the battery protection circuitry by:
   - ensuring that there are no electrical short circuits across the battery terminals.
   - ensure that there are no voltages present which could apply a charging voltage.
4. Once the protection circuit has been verified remove the battery. The battery is siliconed to the assembly. It may be necessary to remove it using a scalpel.
5. Store the battery individually in an anti-static (dissipative) bag or suitable non-conductive packaging.
6. After replacing the battery secure it using a tie wrap. This should be secured from the top of the A2 processor assembly. The recommended tie wrap part number is 1400-1154.
7. Replace the A2J1 link.

WARNING **This power meter uses a lithium battery which may explode if mishandled. The battery should not be subjected to short circuit of the battery terminals or to excessive heat.**

Do not recharge this battery or dispose of it by burning. Check local country regulatory requirements on the disposal of lithium batteries.



Removing the A3 Front Panel Assembly

1. Disconnect the following cables from the A2 processor assembly:
   - power reference semi-rigid (When replacing use the torques detailed on page 5-17.)
   - front panel keypad
   - front panel LCD

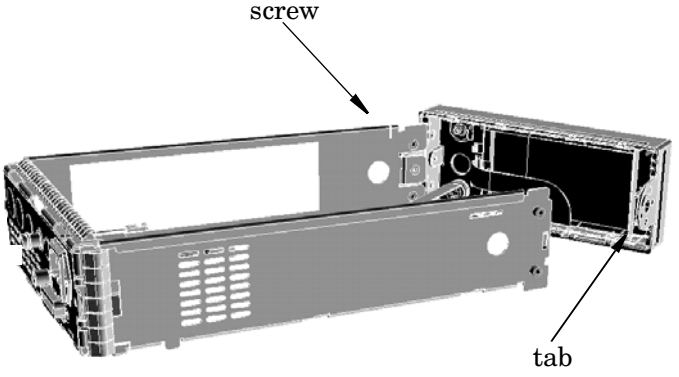
Note Care should be taken when disconnecting the front panel keyboard and LCD. Remove the cables by pulling straight up from the connectors.

2. Disconnect the flex circuit from the measurement assembly.

Note Care should be taken when disconnecting the flex circuit from the measurement assembly.

The flex circuit assembly is released by pushing the connector tab forward and lifting.
To replace the flex circuit, loop it as shown on page 5-16, and connect the flex circuit as shown in the figures on page 5-11.

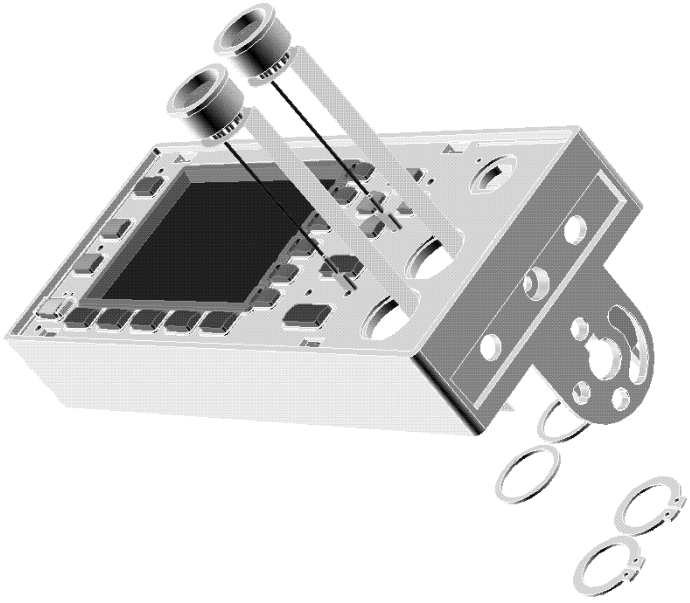
3. Remove the center screw from the right hand side of the front panel.
4. Remove the front panel by pressing in the metal tab on the front panel as shown and push down on the side of the chassis until the standoffs are cleared from the holes.

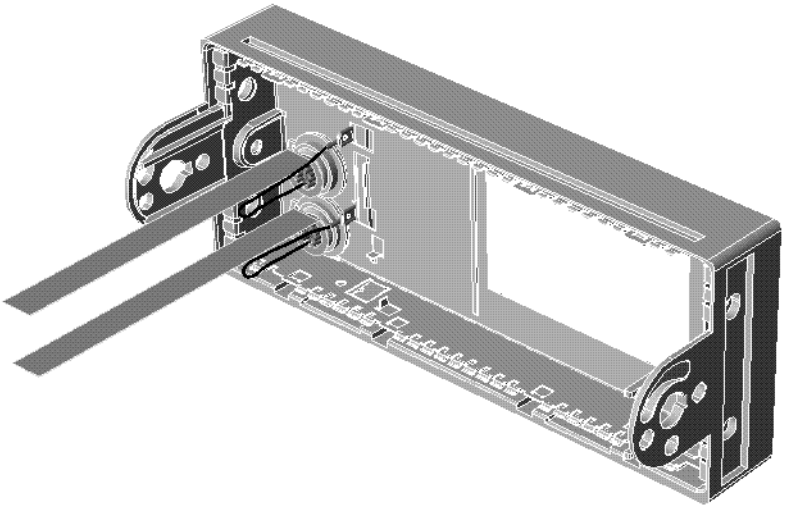


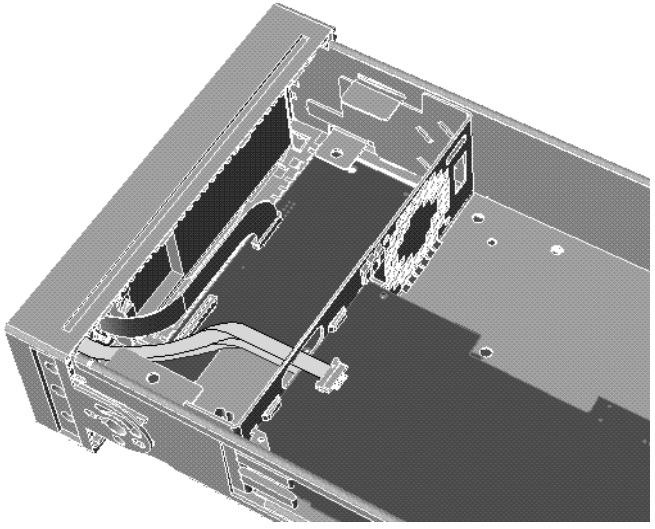
Note After replacing a front panel assembly, the display brightness and contrast must be adjusted. Refer to Chapter 3 “Adjustments”.

Replacing the Front Panel Power Sensor Cable Assemblies

1. Remove the front panel from the power meter. (Refer to “Removing the A3 Front Panel Assembly”, on page 5-14 for details on removing the front panel.)
2. Replace the power sensor cable assembly(s) using the replacement kit.

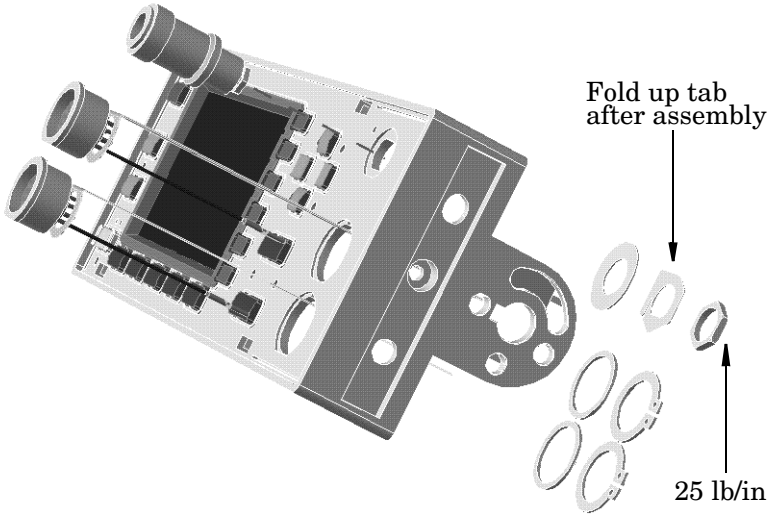


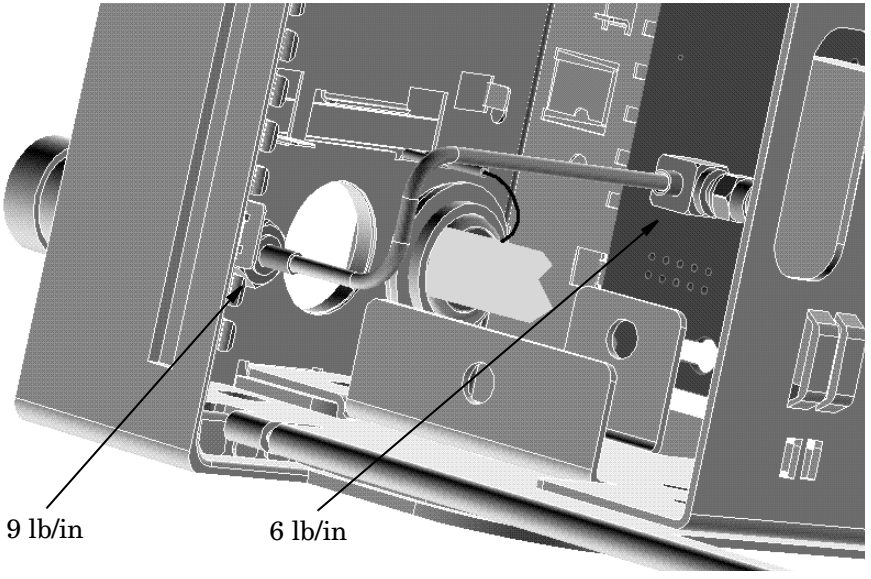




Replacing the Front Panel Power Reference Cable Assembly

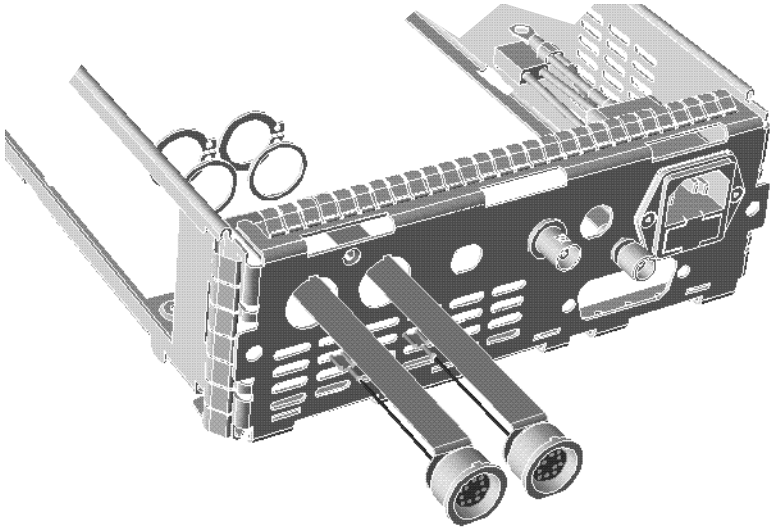
1. Remove the front panel from the power meter. (Refer to "Removing the A3 Front Panel Assembly", on page 5-14 for details on removing the front panel.)
2. Replace the power reference output cable assembly using the replacement kit and the torques indicated on the following diagrams.

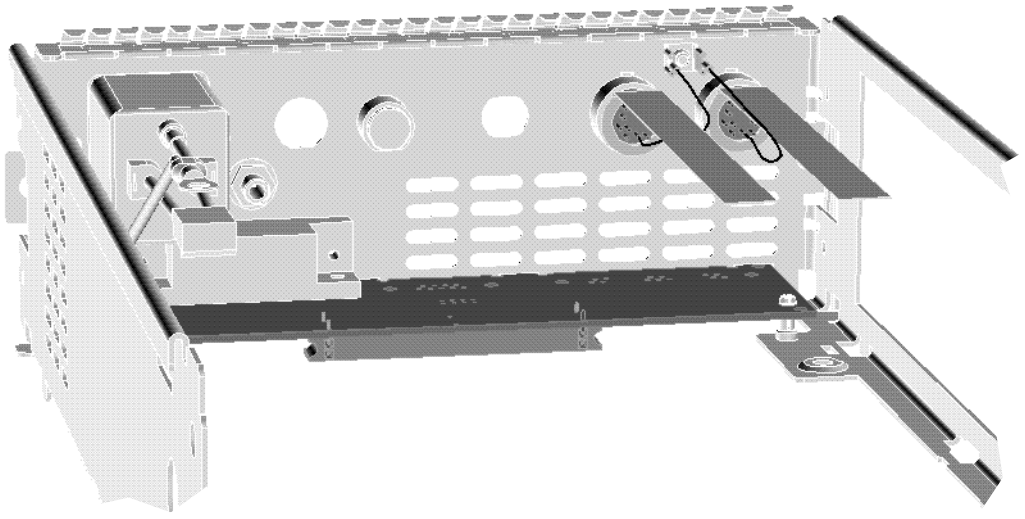


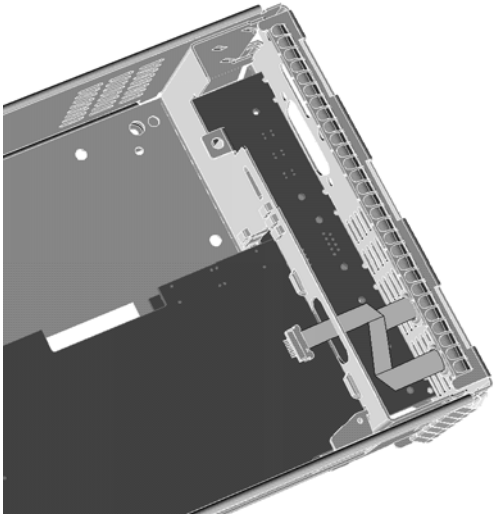


Replacing the Rear Panel Power Sensor Cable Assemblies (Options 002 and 003)

1. Disassemble the power meter to allow access to the rear panel connectors. This is done by following steps 1 through 3 of the A4 interface assembly removal procedure on page 5-10.
2. Replace the power sensor cable assembly(s) using the replacement kits. The inner recess on the power sensor cable is used to locate the circlip when assembling to the rear chassis.

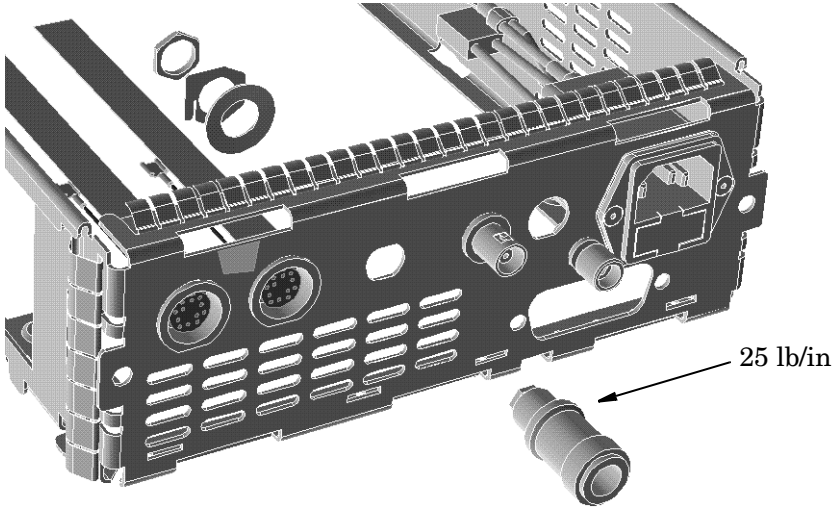


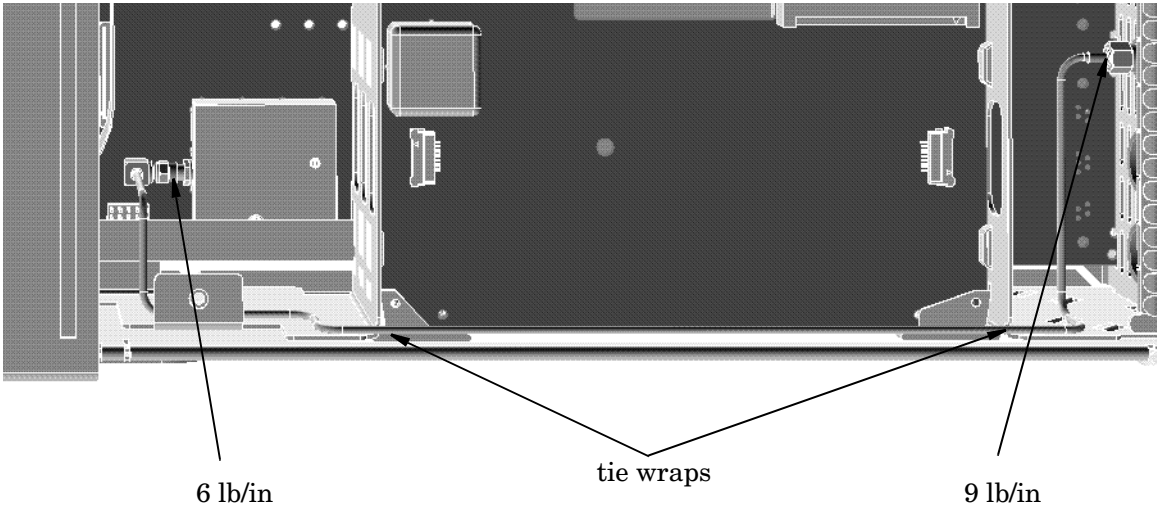




Replacing the Rear Panel Power Reference Cable Assembly (Option 003)

1. Disassemble the power meter down to allow access to the rear panel connectors. (Refer to "Removing the A4 Interface Assembly", on page 5-10.)
2. Replace the power reference cable assembly using the replacement kit and the torques indicated on the following diagrams.





Index

A

A1 power supply assembly 4-3
A2 processor assembly 4-4
A3 front panel assembly 4-7
A4 interface assembly 4-8
A5 daughter assembly 4-9
A6 measurement assembly 4-10
absolute accuracy, specification 1-4
accuracy, of power reference 1-5
address
    of Hewlett-Packard ix
adjustments 3-2
    display brightness and contrast adjustment 3-12
    power reference oscillator frequency adjustment 3-4
    power reference oscillator level adjustment 3-6
altitude characteristic 1-14
assembly part numbers 5-3

B

battery replacement 5-13

C

calibration cycle 2-4
caution v
characteristics 1-2
CLIPs package viii
connector, Recorder Output 1-13
connectors
    HP-IB 1-13

D

danger v
daughter assembly
    description 4-9
    replacement 5-11
dimensions of instrument 1-15
display
    resolution, specification 1-3
    units, specification 1-3
documents viii

E

environmental characteristics 1-14

F

fan assembly replacement 5-12
firmware upgrades 5-6
frequency adjustment 3-4
frequency range 1-13
    specification 1-3
frequency, characteristic of power reference 1-6
front panel assembly 4-7
    replacement 5-14
front panel repair 5-5

H

Hewlett-Packard
    offices ix
HP E-series power sensor
    functional test 2-15
    interface test 2-14
HP-IB
    connector characteristic 1-13
humidity characteristic 1-14

I

IEC 1010-1 vii
instrument accuracy test 2-7
interface assembly 4-8
    replacement 5-10

L

legal information iii

level adjustment 3-6
line power characteristic 1-13

M

markings vi
measurement
    noise characteristic 1-7
    noise definition 1-12
    speed 1-6
measurement assembly description 4-10
measurement assembly replacement 5-11
memory 1-16

N

noise, characteristic 1-7
non-volatile memory 1-16

O

operating environment 1-14
operation 4-2
oscillator adjustment 3-4, 3-6

P

packaging for service xii
parts 5-2
performance test record 2-18
performance tests 2-2
    HP E-series power sensor functional test 2-15
    HP E-series power sensor interface test 2-14
    instrument accuracy test 2-7
    power reference
        level test 2-10
    zero test 2-5
post-repair adjustments 3-3
power
    sensors 1-3
power characteristic 1-13
power output, specification 1-5
power range, specification 1-3
power reference
    characteristics 1-6
    oscillator frequency 3-4
    oscillator level adjustment 3-6
    specification 1-5
power reference cable
    replacement 5-17, 5-20
power reference level test 2-10
power sensor
    cable replacement 5-15, 5-18
power supply
    assembly description 4-3
    replacement 5-8
processor assembly
    description 4-4
    replacement 5-9

R

Recorder Output connector
    characteristic 1-13
relative accuracy, specification 1-4
replace
    battery 5-13
    daughter assembly 5-11
    fan assembly 5-12
    front panel 5-5, 5-14
    interface assembly 5-10
    measurement assembly 5-11
    power reference cable 5-17, 5-20
    power sensor cable 5-15, 5-18
    power supply 5-8
    processor assembly 5-9
replaceable parts 5-2
returning for service xii

S

safety v, 1-15
sales and service offices ix
service
    offices ix
    packaging for xii
    returning for xii
settling time, characteristic 1-9
single sensor dynamic range, specification 1-3
size of instrument 1-15
specifications 1-2
speed of measurement 1-6
SWR, characteristic of power reference 1-6

T

telephone numbers of Hewlett-Packard ix

temperature characteristic 1-14
test equipment 2-3
test record 2-18

U

upgrades 5-6
user's guides viii

V

voltage 1-13

W

warm-up 1-2
warning v
warranty iii
weight of instrument 1-15

Z

zero
    drift definition 1-12
    drift of sensors, characteristic 1-7
zero set
    definition 1-12
    specification 1-4
zero test 2-5